Understanding the Value of Water in Agriculture: Tools for Negotiating Water Transfers

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This guidebook is part of an ongoing series intended to assist public agencies, non-profit organizations, irrigation districts, cities, and businesses with design and implementation of water acquisition programs to improve water supply reliability during drought and under climate change. Other titles in this guidebook series include: *Water Auction Design for Supply Reliability: Design, Implementation and Evaluation; Dry-year Water Supply Reliability Contracts: A Tool for Water Managers;* and *Water Banks: A Tool for Enhancing Water Supply Reliability*. Each of the guidebooks may be retrieved at http://ag.arizona.edu/arec/people/profiles/colby.html.

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Overview of Guidebook

In many semi-arid regions across the world, reliable water supplies already are fully allocated. When these regions face water supply cutbacks due to drought, they have no surplus water supplies to draw upon and some water users necessarily must decrease their use or arrange for access to alternative supplies. Better understanding of the economic value of water will become an increasingly valuable tool for negotiations over water among diverse stakeholders. Water stakeholders in arid regions typically include farmers, cities and towns, industries, households, non-governmental organizations concerned with environmental water needs and public health, and government agencies at local and national levels.

This guidebook focuses upon the arid regions of the western U.S. and northwestern Mexico, although the tools it describes are applicable in regions worldwide. Water supplies in the western United States and northwestern Mexico have historically been subject to extreme flood and drought. Climate change is expected to exacerbate variability in precipitation and water supply, as well as to affect water demand through increased temperatures (Hartmann 2005; Garrick and Jacobs 2006; Rajagopalan, et al. 2009; Kenney, et al. 2010). Population growth contributes to added uncertainty in predicting future water demand and adequacy of supply.

Specialized water acquisitions oriented to improve supply reliability (and described in the other three guidebooks in this series) are likely to become an important adaptation strategy for water managers to meet the challenges of increasingly unreliable water supplies. During periods of water scarcity, water can be temporarily transferred to uses which would otherwise experience a reduced supply. These transfers depend upon successful negotiations with water users who have reliable supplies – primarily farmers and irrigation districts. Among the challenges that a water buyer must confront when engaging in a water transfer negotiation is to identify a price range that an agricultural water user is likely to accept and to avoid paying an excessive price. Generally, a buyer is interested in paying the lowest price that the seller will accept, while a seller is interested in receiving the highest possible price. But what is the value of agricultural water to growers? One method for analyzing the on-farm value of water is through a farm budget analysis based upon Net Returns to Water (NRTW). This guidebook outlines the steps needed to better understand the value of water in negotiations with agricultural water users. Examples to illustrate calculations of NRTW are provided for southwestern Arizona, western Colorado, and the Mexicali Valley in northwestern Mexico. .

Knowledge of NRTW can be viewed as analogous to reviewing “blue book” values (in Mexico, commonly referred to as Autométrica) in the process of buying a used car, where the values provide an objective estimate for the price of a car.[1] While the buyer and seller may have legitimate disagreements over which blue book value is most applicable and which adjustments are appropriate, the blue book is still a useful tool. Similarly, background information from publically available sources on NRTW (as described in this guidebook) is helpful in negotiating water acquisitions.

Why a Focus on Agricultural Water Supplies?

Throughout the arid regions of the world, irrigated agriculture is a major water user. In the United States, irrigation consumes over 80% of all water nationwide (USDA ERS 2004). In Mexico, agriculture also has the highest consumptive use of water, at 78% (Urbina Soria y Martinez Fernández 2006, 193). While a portion of a region's crop irrigation may be essential to local food supplies, irrigation of some crops may be temporarily suspended in order to provide essential water supplies to water users who otherwise face significant losses and hardships. These other users may include households, cities, electric power plants, manufacturing facilities and environmental programs designed to protect water quality and habitat for threatened species. When farmers are compensated for the lost income due to not irrigating crops, and irrigation for essential local food supplies is maintained, voluntary agreements that temporarily shift water use from crop irrigation to other uses can spare a regional economy some of the disruptions that water shortages create. Jobs, safe drinking water supplies and valuable natural habitat that otherwise are in jeopardy can be preserved.

The legal system for allocating water also plays a key role in explaining the focus on agriculture as a source of water for other sectors during times of shortage. In many river basins in the western United States, agricultural water users have the most senior entitlements along with high volumes of water consumption. Due to generally lower priority legal entitlements, urban and industrial users are more likely to face reduced water allotments in a drought than agricultural water users. In many cases, municipalities may be willing to pay a premium for access to secure water supplies because of the high costs of shortfalls of reduced water supply. These costs may range from the costs of household water rationing to the costs associated with complying with environmental regulations during drought, such as providing habitat flows under the Endangered Species Act (in the United States), or meeting water quality standards.

The prioritization of water rights, the legal systems, and regulations are different in Mexico, where municipal water rights typically have priority over agricultural water rights. Yet water scarcity

[1] For reference, the Kelley Blue Book website can be accessed via the following URL: http://www.kbb.com/
The Autométrica: Reportes del Mercado Automotriz website can be accessed via the following URL: http://www.autocosmos.com.mx/autos/usados/precios.aspx

remains a pressing issue and a market for water transfers among agriculturalists is already emerging in the Mexicali Valley Irrigation District (Carrillo 2009). And, inter-sectoral water transfers are increasingly sought as one solution to increasing water supply reliability in the Mexican state of Baja California, accompanied by improvements in conveyance infrastructure (though conveyance improvements may not be necessary in the case of water transfers to the environment) (Medellin-Azuara et al. 2009). Given these ongoing discussions, a better understanding of the process for calculating the value of water in agriculture will be an indispensable tool for negotiating water transfers in both the western United States and Mexico.

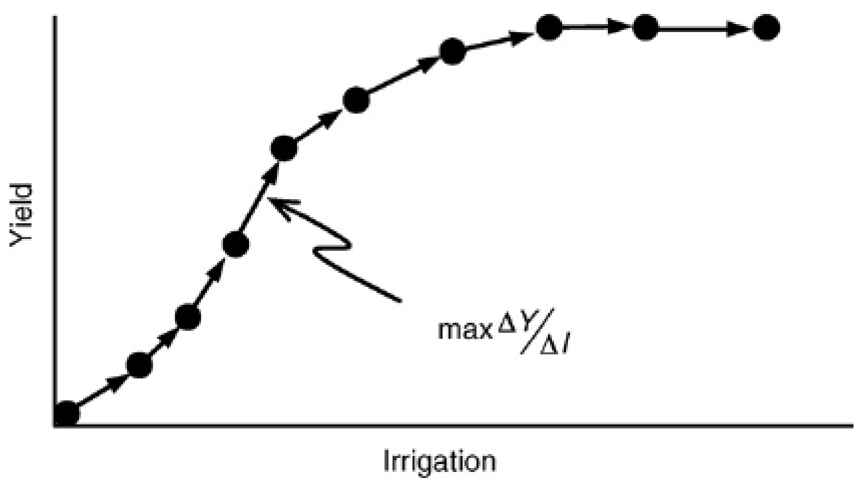
Assessing the Value of Water in Agriculture

There are several ways to assess the value of water in agriculture. The most direct is comparing recent market transaction prices for similar types of water transfers in the same area. However, this approach requires the availability of and collection of actual water transaction data in a specific region. The results are then used as a benchmark for price negotiations. For a market-based comparison to be effective, an active market with regular transactions over a period of years and accurate information about the terms of transactions are necessary (Young 2005). If there are few market participants, relatively few recent transactions, or price information is held confidentially, accurately estimating the value of water based upon market price comparison may be impossible. An example of a publically available database on water transactions in the western U.S. can be found at the website of the Bren School of Environmental Science and Management, University of California, Santa Barbara.[2]

Another approach used to assess the value of agricultural water is through water-crop production functions, which model the relationship between irrigation water and crop yield. Figure 1 represents graphically a generic relationship, where initially an increase in water increases crop yields, but eventually water volumes reach a sufficiently high level that yield no longer increases, and may even decrease with subsequent irrigation applications. The water-crop production function may also be estimated through simulation of the crop growth process through computer modeling (Brumbelow and Georgakakas 2006). With both of these methods, assumptions must be made about the level of other crop production inputs including fertilizers, pesticides and labor used (de Juan et al. 1996). This approach is labor and data intensive, and limited to locations and crops where accurate, up-to-date water-crop production functions are available.

[2] California Water Transfer Records, University of California, Santa Barbara, at http://www.bren.ucsb.edu/news/water_transfers.htm.

Figure 1. Crop-water production function (Brumbelow and Georgakakas 2006, 155)



NRTW is another approach for assessing the value of water used for agriculture. It estimates the on-farm economic value of water in crop production. It is calculated by subtracting variable production costs (excluding water costs) from gross revenues per acre (Gibbons 1986).[3] In other words, the value of water is estimated to be the difference between gross crop revenues and non-water input costs (Naeser and Bennett 1998). This represents the maximum amount that a grower could pay for water and just break even. The NRTW calculation also requires data collection which may be labor intensive, especially in areas where crop production cost data is not easily available. Despite the labor intensive aspect of the NRTW calculation, this process has advantages compared to both the crop-water production function and the market price comparison methods. The benefits of the NRTW method are that it is accessible across broader scales and less expensive than the crop-water production function method and that it can be applied to the many regions where data is not available for the market price comparison method.

NRTW, as discussed here, is useful in negotiating the appropriate price range for an acre-foot of consumptive use that can be transferred to another location and purpose of use. NRTW calculation is straightforward when the necessary data are available. However, many other factors are important to successful negotiation and implementation of a temporary water transfer and must be considered in addition to the price negotiation itself. Legal and regulatory requirements can be complex and are not covered in this guidebook series, as these vary considerably and are best discussed with attorneys and regulatory experts. Transfer of water and change in use is regulated in different ways depending on the type of water entitlement involved. For instance, if water used

[3] Another approach is to consider both variable and fixed costs of production in the NRTW assessment (Young 2005). However, only variable costs are utilized in this analysis because the short-run value of water is of interest.

under a contract with a governmental agency is proposed to be temporarily transferred to other users - then various additional regulations likely will be applicable, beyond those that apply when privately owned water entitlements are transferred. Those who wish to engage in such transfers need to confer with representatives from applicable government agencies for more information on relevant regulations. In the western U.S., attorneys and other experts frequently are consulted to assist in accomplishing water transfers. In the case of Mexico, the government holds priority rights for all water and through concessions may grant use to private parties, such as farmers or industries. Despite multiple differences between U.S. and Mexican water law, the implications remain the same – consulting a lawyer may be necessary to navigate the legal aspects of water transfers.

The determination of the quantity of water that can be transferred is subject to applicable government regulations. In the western U.S., typically only the consumptive use portion of a farm's surface water diversions or groundwater pumping can be transferred, consistent with a "no harm" principle applied to regulating water transfers. The policies and procedures for defining and measuring this quantity vary considerably across jurisdictions and types of water use.

The following section describes the NRTW approach in detail. Subsequent sections provide examples of how it is calculated in practice, using key crops and economic data from western Arizona, western Colorado, and the Mexicali Valley of Baja California, Mexico.

Net Returns To Water Procedure and Analysis

Although permanent water transfers are common in the southwestern United States, the purpose of this guidebook is to focus on the role of NRTW in temporary water transfers as part of forbearance programs. Forbearance programs are characterized by temporary cropland fallowing, where farmers receive payment for not irrigating a portion of their land that is normally irrigated. There are many reasons why cropland may lie fallow in active agricultural areas. Growers may refrain from planting a crop due to low crop prices and/or high input costs which make a specific crop unprofitable, or due to soil management and agronomic factors. In the United States, some federal agricultural programs provide incentives for cropland fallowing. However, this guidebook focuses on irrigation forbearance programs designed to reduce consumptive use in crop irrigation in order to make water available for other purposes. NRTW can be helpful in identifying the payment range that a grower may accept per unit of water consumed in order to refrain from irrigating a particular crop. [4]

[4] The use of options contracts in a forbearance program is fully discussed in another guidebook in this series titled, "Dry-Year Water Supply Reliability Contracts: A Tool for Water Managers." The paper is located on the University of Arizona Agricultural and Resource Economics Department website at http://ag.arizona.edu/arec/people/profiles/colby.html In this paper, fallowing and forbearance are used synonymously.

The calculation is relatively straightforward and is useful in informing water transfer negotiations. Gibbons (1986) and Colby, Pittenger and Jones (2007) provide a framework for calculating NRTW by following a series of steps. First, select key crops in a region that are likely candidates for involvement in a forbearance program (typically, high value perennial crops such as orchards and vineyards are not likely candidates). Second, begin the process of compiling a crop budget by describing the operations and inputs for each candidate crop. Third, gather data on the steps in the production process, seasonal timing, required production inputs and their costs, and resulting crop yields (generally obtained from farmer and agricultural extension agent interviews). The data is used to produce a crop and location specific budget. Finally, use this data to calculate NRTW per acre-foot for each crop. The value obtained reflects an on-farm net return to water in crop production. This NRTW is calculated by subtracting variable production costs (excluding water costs) from gross revenues per acre. Stakeholders will generally not need to create a new crop budget in each instance. Access to necessary information is supported in many states through the crop production budgets produced by agricultural economists at land grant colleges in the United States or by SAGARPA in Mexico (see Appendix A for list of sources; see Appendix G for a bilingual list of acronyms used in this guidebook).

For stakeholders with a background in business, it may be helpful to compare a crop budget to a company's income statement. With a similar layout as the crop budget, an income statement lists (simplified for the example) *gross revenues*, *expenses*, and *net income*. The analogous terms in the crop budget are the *gross revenues*, *costs* (divided into variable costs and fixed costs) and *net returns* (also called *net returns to management and risk*). Refer to Table 1 for a list of definitions of terms used in the guidebook.

Given the heterogeneity of farms across a given region, one challenge in creating accurate crop budgets is reflecting that diversity while maintaining a general model that can be widely applicable. County-level crop budgets, created by land grant universities in many U.S. states, seek to represent "typical" farms within a county and must make assumptions about variables such as soil quality, use of inputs and labor, and market access. In this guidebook, the examples represent a specific subset of crop production in Yuma County, Arizona, in western Colorado, and in the Mexicali Valley of Mexico. However, the farms that grow the crops used in these examples will not be equally productive or have identical cost structures. Specific farms and irrigation districts may differ substantially from the examples provided.

Additionally, crop budget analyses are sensitive to the assumptions made about input and output prices and quantities. Input costs, for instance, can vary from farm to farm. Consequently, the input costs listed in a crop budget may not reflect actual conditions on a specific farm (Young 2005). Input costs are estimated by listing and collecting cost data on all of the required activities to be completed during the preparation, planting and harvesting cycle. Inputs include seeds, fertilizers, pesticides, herbicides, and labor. Information in published crop budgets on input costs is often obtained directly from interviews with agricultural and chemical suppliers. Prices quoted by agricultural and chemical suppliers may not represent the prices actually paid by growers, because some growers may bargain with suppliers to obtain reduced prices due to long term relationships or volume discounts.

Also, NRTW does not take into account the inherent risk in agricultural production and risks in the market for crops produced, or growers' perceptions about risks of participating in forbearance programs. A grower may be willing to accept *less than* NRTW as payment for water depending on their perceptions of risk and their risk preferences. Therefore, in the context of a crop portfolio analysis, a farmer may consider a guaranteed fallowing payment to be less risky than a potential future payment for a harvest. Although risk and risk preferences are not inherent in the NRTW calculation, they are considered in a later section of this guidebook titled Risk Considerations for Crop Portfolios, with instructions on calculating various measures of risk included in Appendix E.

Finally, for new and proposed agricultural crops, and for crops that are certified organic, published crop budgets are unlikely to be available. Despite these difficulties and limitations, NRTW can improve the understanding of the economic value of water in irrigated agriculture from a specific region. The NRTW figures are effective tools when accurate, site-specific data can be located, and can contribute to more informed negotiations between potential water buyers and agricultural water users. The following table, Table 1, provides definitions for general terminology that will be used in subsequent sections of this paper.

Table 1: Terminology and Definitions

Terminology	Definition
NRTW	Net Returns to Water represents the maximum cost that a farmer could pay for water and still just break even in producing a specific crop. NRTW is calculated as gross revenues per acre (or hectare) minus variable costs (exclusive of water costs), and is a useful benchmark in water transaction negotiations. (Refer to Appendix H for the conversion for acres to hectares, as well as a complete table of conversion for units of measurement used in this guidebook).
Crop and Agricultural Consumptive Use	The consumptive use is the volume of water that the crop consumes during the production cycle, either through incorporation into plant biomass or through evapotranspiration, and which is not directly returned to the local hydrologic system as either seepage into groundwater aquifers or as surface water runoff. Agricultural consumptive use can also include evaporation from the surface of fields and from irrigation district water delivery canals. This quantity differs from water applied during crop production (Scheierling, Young, and Cardon 2004). More information regarding the consumptive use of water in agriculture can be found in Appendix F.
NRTW Per Acre-Foot of Water Consumed	This is the value of the NRTW divided by the acre-feet of water consumptively used in the production of that crop.
Variable Costs	Variable costs are costs that can be changed during the course of the seasonal crop production cycle. These costs include pesticides, seeds, fertilizer, and labor. They can be thought of as costs related directly to the acreage planted and quantity of crop harvested, from preparing the land to post-harvest costs.
Fixed Costs	Fixed costs are costs that cannot be altered simply by altering the amounts of inputs used during crop production. Fixed costs include property tax payments, machinery and capital equipment, ownership expenses, management salaries, and other expense obligations that do not vary with yields and harvest levels.
Federal Farm Support Payments	Federal farm support payments are United States government payments to farmers. These vary greatly among crops and farms eligible for payments. Some payments are tied to specific yields while other support payments are de-coupled (meaning that they are not linked to specific crop yields). Loan deficiency payments

	(LDPs), are linked to a specific yield and therefore are included in the Yuma County NRTW calculations for Upland cotton.
Net Returns to Management and Risk	Net Returns to Management and Risk is a term used by agricultural economists for the total revenues minus total costs (costs includes variable and fixed costs).

Net Returns to Water: Practical Applications from Southwestern US and Northwestern Mexico

The next three sections of this guidebook provide practical examples of NRTW calculations from agricultural regions located in Arizona, U.S., Colorado, U.S., and Mexicali Valley, Mexico. While the process of calculating NRTW for key crops is similar across regions, these three examples illustrate the calculation process using differing sources of available data. All tables in this guidebook were compiled by the authors of this document, drawing upon information from primary sources. All U.S. crop budgets were adjusted for inflation using Consumer Price Index (CPI) tables provided by the U.S. Bureau of Labor Statistics, and Mexican crop budgets were adjusted for inflation using Indice Nacional de Precios al Consumidor (INPC) tables provided by the Banco de Mexico. In all three sections, values are listed in USD (U.S. dollars) and MXN (Mexican pesos), and all currency conversions were applied after adjusting values for inflation, using exchange rates from Oanda (Oanda 2011). Adjustments for inflation and conversion between USD and MXN are provided to enable readers to make direct comparison of the NRTW across regions.

The section on Arizona uses Yuma County data on NRTW for the period from 2002-2009. The NRTW for the four crops discussed, which are Durum wheat, alfalfa, Upland cotton, and head lettuce, show fluctuations throughout the time interval. The implications are two-fold. First, the examples reinforce the point that the NRTW is a range, not a single value. Second, the data and calculations can provide valuable information to farmers and other stakeholders regarding recent trends in major crops returns, aiding in the decision making process. Next, the section on western Colorado illustrates the step-by-step process for calculating the NRTW for corn, further helping the readers to understand the computation process. The section on Mexicali Valley, Mexico, serves to reinforce the concept that the NRTW concept is broadly applicable across regions as the crop budgets utilized, for wheat and cotton, are in a similar format as the U.S. crop budgets, facilitating comparison of NRTW calculations. Mexicali Valley can be considered representative of agricultural production in the Mexican state of

Baja California, given that encompasses 87% of total agricultural production for the state (SAGARPA 2009).

Yuma County, Arizona, Net Returns to Water

In this section, we demonstrate the process of computing NRTW for key crops in Yuma County, Arizona and report these NRTW values over a period of recent years. The NRTW is calculated by taking gross revenues (which are the crop price multiplied by total yield per acre) and subtracting variable costs of production (excluding the cost of water). Mathematically, this can be seen as follows:

NRTW = Price*(Yield/acre) – Variable Costs

The per-unit value of water is of interest in this study, so the result is divided by the crop-specific volume of water consumed per production acre. It is important to calculate NRTW based on farm consumptive use rather than water applied per acre, because typically water transfer policies allow only the consumptive use portion to be moved to other locations and uses. The consumptive volume estimates used in this study for Yuma County are obtained from the Bureau of Reclamation's Lower Colorado River Accounting System (LCRAS), and a six-year average consumptive use was calculated (see Appendix F for the annual consumptive use values)(Bureau of Reclamation 2002-2008).

The 2002-2006 and 2005-2009 average crop prices and input costs reported in Tables 2, 3, 4, and 5 are based on input costs from University of Arizona crop budgets (Teegerstrom and Knowles 1999; Teegerstrom and Tickes 1999; Teegerstrom, et al. 2001). [5] All fertilizer, insecticide and herbicide prices were updated through personal interviews with input suppliers in fall 2009. Yields and commodity prices come from Arizona Agricultural Statistics Bulletins (USDA 2003; 2004; 2005; 2006; 2007; 2008; 2009; 2010).[6] The 2002-2006 data was updated from Jones (2008). After finishing the calculations, all values were updated to April 2011 USD using data from a CPI inflation table provided by the Bureau of Labor Statistics (US Bureau of Labor 2011). Values in the final column of the tables were then converted to Mexican pesos using April 2011 currency rates (Oanda 2011). For a detailed summary of input costs and the NRTW calculation for Yuma, see Appendix B.

Tables 2, 3, 4, and 5 present data on NRTW per acre-foot of water for Durum wheat, alfalfa, Upland cotton and head lettuce in Yuma County, Arizona. The data is divided into separate rows (per acre) for yield, price per unit, gross revenue, variable costs (excluding water costs), net returns to

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[5] The years 2002-2006 and 2005-2009 were selected to accommodate data availability issues.

[6] With the data for Yuma County, 1 bushel of wheat = 27.22 kilograms; 1 ton (also referred to as a short ton) = 907.18 kilograms; 1 cwt = 100 pounds = 45.36 kilograms; and 1 acre = 0.405 hectares. A complete conversion table can be found in Appendix H.

water, and acre-feet of water consumptively used. By separating the components, the reader can view which variables are influencing the fluctuations in the NRTW across time periods. Each table contains a column of average values for the years 2002-2006, a column of average values for the years 2005-2009, and a column showing the percent change of those two averaged series (negative values, or decreases, are in parenthesis). The Upland cotton table contains the average values for the years 2006-2008 instead of 2005-2009 because a full set of data was not available for the relevant five-year comparison. Also in the case of cotton, loan deficiency payments (LDP) are listed. An LDP is a governmental payment to growers when the market price of cotton falls below a certain threshold.

Table 2: NRTW, Durum Wheat

Yuma Durum Wheat 5-year Average (in 2011 USD)				**Yuma Durum Wheat (in 2011 MXN)**	
Years	**2002-2006**	**2005-2009**	**% Change**	**2002-2006**	**2005-2009**
Revenue per Acre					
Bushels/acre	102	106.1	4%	102	106.1
Price($)/bushel	4.62	6.68	44%	54.11	78.12
Gross Revenue ($/Acre)	471.71	708.40	50%	5518.98	8288.32
Variable Costs per Acre($)	391.22	560.75	43%	4577.28	6560.78
Net Returns to Water per Acre($)	80.49	147.65	83%	941.70	1727.53
AF water consumptively used per acre	1.9	1.9		1.9	1.9
Net Returns to Water Per Acre-foot of Water Consumed($)	**42.36**	**77.71**	**83%**	**495.63**	**909.23**

Table 3: NRTW, Alfalfa

Yuma Alfalfa 5-year Average (in 2011 USD)				**Yuma Alfalfa (in 2011 MXN)**	
Years	**2002-2006**	**2005-2009**	**% Change**	**2002-2006**	**2005-2009**
Revenue per Acre					
Tons/acre	9.3	9.3	0%	9.3	9.3
Price($)/tons	112.05	143.47	28%	1310.98	1678.58
Gross Revenue ($/Acre)	1042.06	1334.25	28%	12192.15	15610.78
Variable Costs per Acre($)	415.04	601.96	45%	4855.94	7042.90
Net Returns to Water per Acre($)	627.03	732.30	17%	7336.21	8567.87
AF water consumptively used per acre	5.5	5.5		5.5	5.5
Net Returns to Water Per Acre-foot of Water Consumed($)	**114.00**	**133.14**	**17%**	**1333.86**	**1557.79**

Table 4: NRTW, Upland Cotton

Yuma Upland Cotton 5-year and 3-year Average (in 2011 USD)				Yuma Upland Cotton (in 2011 MXN)	
Years	**2002-2006**	**2006-2008**	**% Change**	**2002-2006**	**2006-2008**
Revenue per Acre					
Pounds/acre (lint)	1323	1397	6%	1323	1397
Price($)/pound (lint)	0.54	0.57	5%	6.31	6.65
LDP($)/pound	0.09	0.03	(69)%	1.09	0.34
Tons/acre (seed)	1.05	1.05	0%	1.05	1.05
Price($)/ton (seed)	155.33	214.88	38%	1817.34	2514.09
Gross Revenue ($/Acre)	1000.54	1060.11	6%	11706.33	12403.30
Variable Costs per Acre($)	1191.24	1270.03	7%	13937.46	14859.32
Net Returns to Water per Acre($)	(190.69)	(209.92)	(10)%	(2231.13)	(2456.02)
AF water consumptively used per acre	3.5	3.5		3.5	3.5
Net Returns to Water Per Acre-foot of Water Consumed($)	**(54.96)**	**(60.49)**	**(10)%**	**(642.98)**	**(707.79)**

Table 5: NRTW, Head Lettuce

Yuma Head Lettuce 5-year Average (in 2011 USD)				Yuma Head Lettuce (in 2011 MXN)	
Years	**2002-2006**	**2005-2009**	**% Change**	**2002-2006**	**2005-2009**
Revenue per Acre					
Cwt/acre	345	342	(1)%	345	342
Price($)/cwt	20.70	17.80	(14)%	242.13	208.20
Gross Revenue ($/Acre)	7139.79	6085.90	(15)%	83535.49	71205.03
Variable Costs per Acre($)	5338.30	3442.14	(36)%	62485.16	40273.02
Net Returns to Water per Acre($)	1801.48	2643.76	47%	21077.33	30932.01
AF water consumptively used per acre	1.3	1.3		1.3	1.3
Net Returns to Water Per Acre-foot of Water Consumed($)	**1396.50**	**2049.43**	**47%**	**16339.02**	**23978.30**

In all cases, except for Upland cotton, a positive value for NRTW per acre is shown in both the 2002-2006 and 2005-2009 time-periods, indicating that revenues exceed variable costs of production. Upland cotton shows a negative value for NRTW per acre for both time periods, indicating that variable costs exceeded gross revenues, even with the federal farm support payment included. In cases where federal farm support payments are not linked to yield, they do not need to be included in the NRTW calculation. However, LDP's for Upland cotton are linked to yield and these have been included for these time periods.

Looking at each line of the tables provides useful information for determining the source of variation. Was it due to a change in gross revenues, a change in variable costs, or both, that led to the changes in NRTW across the two time periods? Specifically, gross revenues for alfalfa and Upland cotton (seed) increased because market price increased in every instance, whereas gross revenues increased for Durum wheat and Upland cotton (lint) because yields and prices both increased. Although alfalfa and Upland cotton (seed) yields remained unchanged, the market price increased, meaning that gross revenue still increased. Lettuce yield and market price both declined, leading to a decline in gross revenue.

The changes in gross revenues and variable costs had impacts on the NRTW in different ways for each crop when comparing the two time periods, even though in every case (except for head lettuce), the gross revenues and variable costs increased from the 2002-2006 average to the 2005-2009 average. Gross revenues for Durum wheat increased from the earlier to the later time period by about 50% while variable costs only increased 43%, meaning that the NRTW for Durum increased. For alfalfa, gross revenues increased by 28% whereas variable costs increased by a greater percentage, 45%, yet this still led to positive NRTW because the initial magnitude of the gross revenues was high enough to buffer the impact of the variable cost increase. Head lettuce, on the other hand, saw a decrease in gross revenues of 15% from the first to second time period, yet the variable costs decreased more than twice as fast, by 36%, leading to an increase in NRTW for lettuce. Finally, Upland cotton had only minor changes in gross revenues and variable costs between the first and second time periods, and the NRTW remained negative in both periods. These fluctuating and often inconsistent trends give the reader a better sense of many of the hidden complications that may influence the negotiation of prices in water transfers.

For the purposes of understanding on-farm water values, the most important value is the NRTW *per acre-foot of water consumed* because that figure provides the benchmark for the payment required for a grower to cease consuming an acre-foot of water. In other words, each crop consumes a different amount of water per acre, so the NRTW per acre-foot of water consumed enables water managers to compare water use among different crops. The comparison provides insight into which crops can be most cost effectively included in a fallowing program, as programs generally seek to acquire water at a low cost per unit of water obtained.

The NRTW per acre-foot for Durum wheat, alfalfa, Upland cotton and head lettuce (averaged over the 2005-2009 time period) was $77.71 USD, $133.14 USD, -$60.49 USD, and $2049.43 USD, respectively. Over the period 2005-2009, the NRTW per acre-foot of water consumed for Durum wheat shows an 83% increase, alfalfa a 17% increase, and head lettuce a 47% increase. Upland cotton, however, shows a 10% decrease. In fact, Upland cotton is the only of the four crops to have a negative value for the NRTW per acre-foot of water consumed for the combined period, 2002-2008, which suggests that Upland cotton growers did not recoup their variable costs.

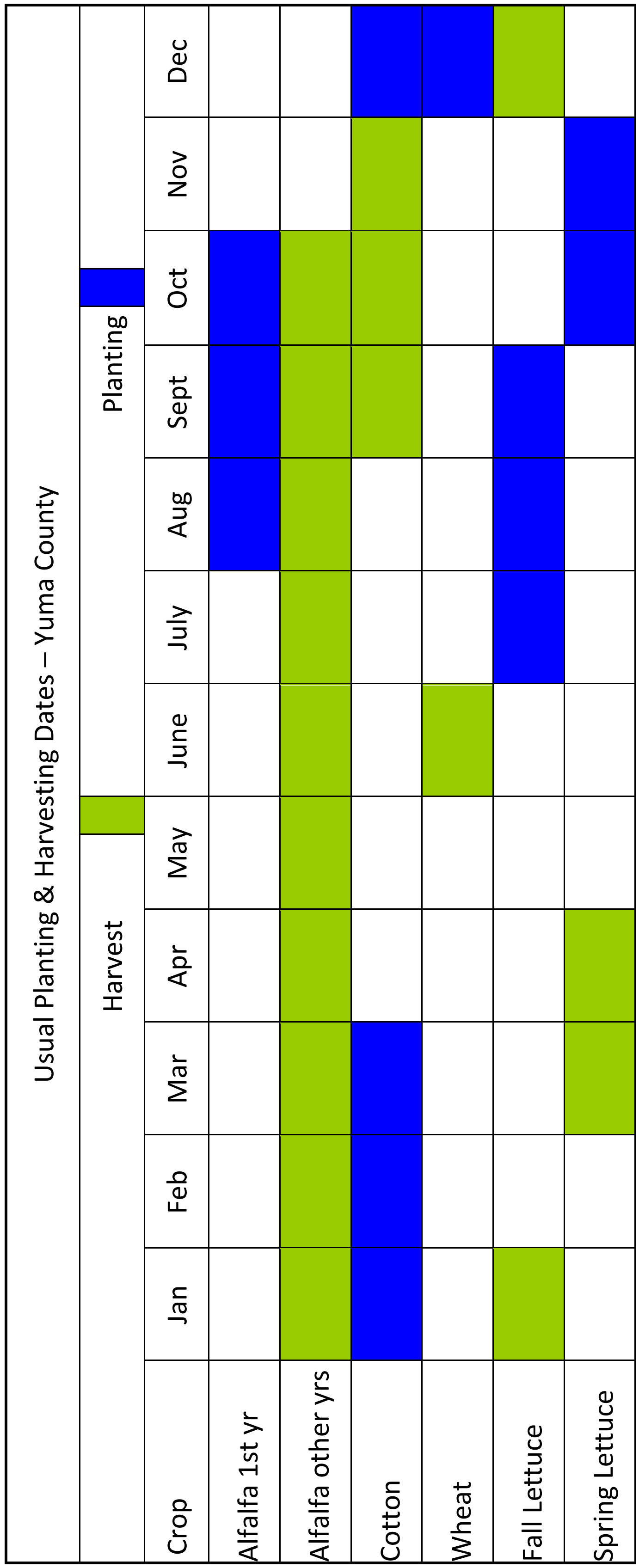
One explanation for the negative values for Upland cotton is that the estimated variable costs in the Arizona crop budgets are higher than growers typically pay; that is, it costs less for the grower to produce than the assumed variable cost figure in the NRTW calculation. Another possibility is related to the compensation that cotton growers receive in the form of LDPs. A farmer must still be classified as an active cotton grower to maintain eligibility and continue receiving these federal farm support payments. Also, the high prices for Upland cotton in spring, 2011, indicate that farmers may have been confident that cotton prices would once again increase.

The large positive value for head lettuce's NRTW suggests high returns in the head lettuce market that would require large payments to growers to convince them to cease irrigating. The lettuce market, however, has a volatile nature and narrow market windows (Teegerstrom 2010). Because the input costs are high, if a grower misses a key market window for harvesting and selling lettuce, the grower may suffer a significant loss due to high costs. The variable costs for lettuce from 2005-2009 were over six times greater than for wheat. The volatile nature of lettuce shows another complexity in the decision-making process - the decision for a farmer as to whether or not to fallow lettuce, and the decision of a potential water buyer to decide whether or not to target lettuce, will vary from situation to situation.

Recall that the NRTW per acre-foot for Durum wheat, alfalfa, and Upland cotton over 2005-2009 time period was $77.71 USD, $133.14 USD, and -$60.49 USD, respectively. The relatively low values make the selection of these three crops attractive for fallowing programs because the price required to pay growers to cease irrigating is correspondingly low. These three crops often are rotated seasonally on the same parcel of land and so a 12-month irrigation forbearance contract might involve all three crops. However, alfalfa is a nitrogen-fixing crop, meaning that alfalfa is capable of increasing the nitrogen content in the soil. Therefore, farmers must consider the benefits of nitrogen fixation in deciding what monetary value they are willing to accept for temporarily fallowing alfalfa. Furthermore, alfalfa fields continue to be productive over multiple years following planting, providing many cuttings a year in southwestern Arizona. The quality of the alfalfa harvested varies seasonally and over the lifetime of the established alfalfa stand and these factors affect the timing and acceptable payments for ceasing to irrigate alfalfa fields.

Crop rotation cycles also should be considered when higher value crops such as lettuce are included in the rotation, which could also lead to an increase in the value of water in the forbearance agreement. Other seasonal timing issues affect the range of payments farmers would consider acceptable as well. The NRTW calculation reflects a value for water beyond the non-water variable costs of production. Therefore, activating a forbearance agreement before the farmer has invested resources in the next crop cycle may enable the farmer to accept a lower payment from the water buyer. In contrast, if a grower has already incurred costs in crop production activities, the grower may request additional compensation related to costs already sunk into the next crop cycle. The chart in Figure 2 illustrates the months of planting, growing, and harvesting cycles for major crops in Yuma based on University of Arizona crop budgets (Teegerstrom and Knowles 1999; Teegerstrom and Tickes 1999; Teegerstrom, Palumbo, and Zerkoune 2001; Jones 2008). The blue cells in Figure 2 denote the important planting windows and the harvest windows are shown in green.

Figure 2: Timing of Planting and Harvesting in Yuma County, Arizona



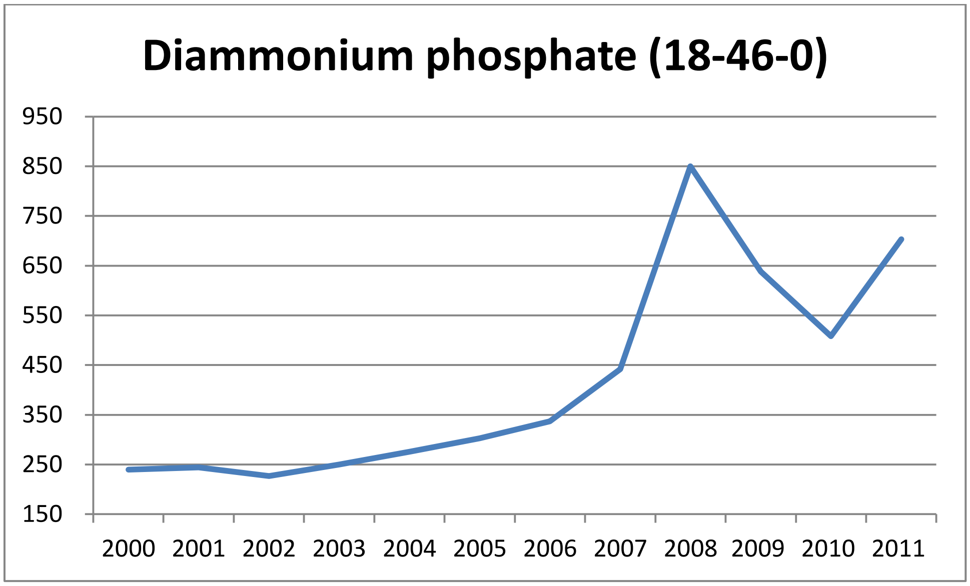
Western Colorado, Another Example for Calculating Net Returns to Water

This section demonstrates the steps in calculating NRTW using an example from the Colorado River Basin in western Colorado. Each step in this section can be generalized with ease, illustrating how the process for calculating NRTW is applicable to regions outside of Arizona. We provide specific instructions to enable stakeholders with various disciplinary backgrounds to understand the calculations. Irrigated corn (grain) was selected as a representative example and the corn crop budget was located on the Colorado State University Extension website, where crop budgets are listed by region and by crop (Colorado State University Extension 2008). Data from the crop budget, used to calculate NRTW, is shown in Table 6. For a detailed summary of input costs and the NRTW calculation for western Colorado, see Appendix C. See Appendix A for more sources for finding regional crop budgets. Refer to Table 1 for terminology and definitions used in this section.

To calculate NRTW, begin by researching the production process and timing for the given crop. In Colorado, corn is typically planted between April 15 and May 15 and harvested in November (McDonald, Hofsteen and Downey 2003). The annual statistical bulletins (compiled for each state) on the USDA National Agricultural Statistics Service (NASS) website are also typically a good resource for planting and harvesting dates by crop, though exact planting and harvesting windows will vary by region within a state. The NRTW calculation varies with differences in physical location of farm and crop produced. The more site-specific the information obtained for a given location and crop, the more accurate the NRTW calculation will be for that site. In some states, crop production data is available at the county level, while for other states that data is compiled for larger areas of the state – as with western Colorado.

Next, review the costs and prices in the relevant version of the complete crop budget and search for current data. Even if the crop budget contains data from the current year, seek updated cost information by consulting local suppliers of agricultural inputs and agricultural extension agents in the region. The costs and prices listed in the budget fluctuate and also represent average prices among farmers, meaning that they can vary significantly from farm to farm. Agricultural input prices can fluctuate significantly over time, particularly as global economic conditions affect the cost of fuel and energy-intensive farm inputs. An example of input price fluctuations is provided in Figure 3, showing phosphorus fertilizer (diammonium phosphate) prices in USD per ton from 2000 to 2011. Consequently, diligence in researching agricultural input prices will result in a more accurate calculation of NRTW. If more recent location-specific variable costs for any inputs are available, update these costs at this time.

Figure 3. Phosphate fertilizer prices in USD/ton from 2000-2011 (USDA ERS 2011)



Continuing with a description of the NRTW calculation process, next locate a current price for the specified commodity and update the appropriate crop price column in the budget. The upper section of Table 6 shows gross revenues from production, which is a function of price and yield. In this example the western Colorado corn price was initially updated with January 2010 prices obtained from the USDA NASS website and entered into the upper section of Table 6, then updated to April 2011 USD using CPI tables (US Department of Labor 2011). The USDA NASS website provides detailed prices and yields data by crop and results can be narrowed by other search criteria such as time period, state, and county.[7] Crops are often classified by quality and producers receive different prices dependent upon the quality, yet crop prices listed in databases and online reports are typically average prices of all quality levels. Therefore, if greater specificity is available in crop prices, use a price that reflects level of quality when possible.

Next, refer to the yield per acre column in the gross revenues section in the specified crop budget. Review the yields per acre to determine if that quantity needs to be updated as well. With changes in technology and climatic changes, yields in a given region will change over time. The unit of measurement for yields may vary per crop, though in this example it is shown in bushels per acre. One must be cautious to use the same unit of measurement for both price and yield data, meaning that since the yield in this example are in bushels, the price information from the USDA NASS website was also obtained in dollars per bushel. Yield information may also be obtained from the USDA NASS

[7] The National Agricultural Statistics Service has a quick link for searching for agricultural commodity prices per state and time period, at http://quickstats.nass.usda.gov/.

website, from cooperative extension websites of regional universities, or from farmers in the region of interest.

Then, locate the section of the crop budget that outlines variable costs. These costs may also be listed in the crop budget as Operating Costs, Direct Costs, Preharvest, and Harvest costs, among other titles. They are still considered, from an economic perspective, as variable costs. Within variable costs, the amount that the grower actually pays for the water itself should be identified and subtracted. Irrigation labor costs will remain in the crop budget, as do any costs paid by the farmer to transport water to the farm. This is because the calculation of NRTW is intended to place a value on the water itself, not on labor related to irrigation or the transport of water. The producer costs were also updated to April 2011 USD using the CPI (US Department of Labor 2011).

Next, identify any fixed costs and remove those costs from the crop budget. The original 2008 crop budget for Irrigated Corn in Western Colorado included a section on Property and Ownership Costs. This category included fixed costs such as machinery and overhead costs, general farm overhead, and real estate taxes. Fixed costs are not included in the calculation of net returns to water for the purpose of valuing water for negotiating temporary transfers.

Finally, locate data on the volume of water used consumptively per acre. The consumptive use value must be specific to each crop, and county level or irrigation district data will be much more accurate than state-wide data. Locations that often publish consumptive use data are the Department of Agriculture website for the relevant state, research articles, or the Bureau of Reclamation (online or in print). For this example, consumptive use data was obtained from a Colorado State University Extension publication, showing a value of 2.1 acre-feet for irrigated corn (grain) in western Colorado (Schneekloth and Andales 2009).[8]

Compute the final calculations, for corn in western Colorado, as follows:

1) Calculate gross revenues by multiplying price per bushel times yields per acre . In Table 6, locate the Value per Acre of Corn produced, 3.59/bushel, and multiply it by 171.50 bushels, to get a value of $616.32 USD.

2) Subtract the total variable costs from the gross revenues, which in Table 6 equals $616.32 USD minus $369.55 USD. NRTW is equal, in this example, is $246.77 USD.

[8] For comparison, consumptive use figures had previously been obtained from the Colorado Department of Agriculture website. The consumptive use values provided from three counties in western Colorado were averaged to get a value of 1.86 acre-feet of water consumptively used for irrigated corn (grain) in that region (Frank and Carlson 1999). Although we use the 2009 values in this publication, it is useful for readers to be aware that consumptive use values change over time with varying climatic conditions. See Appendix F for more on consumptive use considerations.

3) The acre-foot of water consumptively used for Table 6 is 2.1. Divide the NRTW, $246.77 USD, by 2.1 to get $117.51 USD. Therefore, the value for NRTW per acre-foot of water consumptively used in this example is $117.51 USD.

Table 6: NRTW, Irrigated Corn, western Colorado (in 2011 USD)

	Unit	Price or Cost/Unit	Yield Per Acre	Value or Cost Per Acre	Value or Cost per Acre (in 2011 MXN)
Gross Revenues from Production					
CORN	BU	3.59	171.50	616.32	7210.92
Total Revenues				**616.32**	**7210.92**
Variable Costs					
Total Preharvest				330.33	3864.87
Total Harvest				39.22	
Total Variable Costs				**369.55**	**458.90**
Net Returns to Water				**246.77**	**2887.15**
AF water consumptively used per acre				2.1	1.86
Net Returns to Water per AF of Water Consumed				**117.51**	**1552.23**

A sensitivity analysis is a useful tool for testing the variation that may occur due to either changes in crop prices or input costs, or climatic and environmental changes. Sensitivity analyses can be easily calculated in Microsoft Excel using the format below as a template. The purpose of a sensitivity analysis is to systematically alter the value of specific variables in order to see the effect. Using the data on irrigated grain corn in western Colorado from Table 6, in April 2011 USD, the sensitivity analysis in Table 7 shows a wider range of possible values for NRTW. Table 7 shows the impacts of increasing or decreasing by 10-20% the prices of the crop and yields.

The NRTW tables 2, 3, 4, and 5 in the Yuma County section and the sensitivity analysis in Table 7 of this section serve to demonstrate the inherent variability in the NRTW over time. Infrequent events can significantly skew yields and prices, such as the February 2-3, 2011 frost in Yuma, after which only 60% of head lettuce was marketable and lettuce prices nearly doubled overnight, from between $12.50 USD and $13.55 USD to around $21.60 USD to $23 USD per 24-count carton (Nolte 2011). Therefore, we recommend that estimates of NRTW used in forbearance contract negotiations consider 3 to 5 year averages for yields, crop prices and for input costs, to compensate for outliers and provide a more accurate representation of crop returns over time. Variability in prices and yields is further discussed in the section of this guidebook titled Risk Considerations for Crop Portfolios. The following section demonstrates how the same calculations that were applied to the western Colorado crop budget can be applied to crop budgets for wheat and cotton from Mexicali Valley, Mexico.

Table 7: Observing Change in NRTW Given Changes in Crop Yields and Crop Prices for Irrigated Corn in Western Colorado (April 2011 USD)

Sensitivity Analysis			**Alternate Prices**				
		Prices	$2.87	$3.23	$3.59	$3.95	$4.31
	Yield	Percent Change	-20%	-10%	0%	10%	20%
Alternative Yields (Bushels/Acre)	137.2	-20%	$24.89	$74.20	$123.50	$172.81	$222.11
	154.4	-10%	$74.20	$129.66	$185.13	$240.60	$296.07
	171.50	0%	$123.50	$185.13	$246.77	$308.40	$370.03
	188.7	10%	$172.81	$240.60	$308.40	$376.19	$443.99
	205.8	20%	$222.11	$296.07	$370.03	$443.99	$517.94

The Mexicali Valley of Baja California, Mexico, Net Returns to Water Calculations for Wheat and Cotton

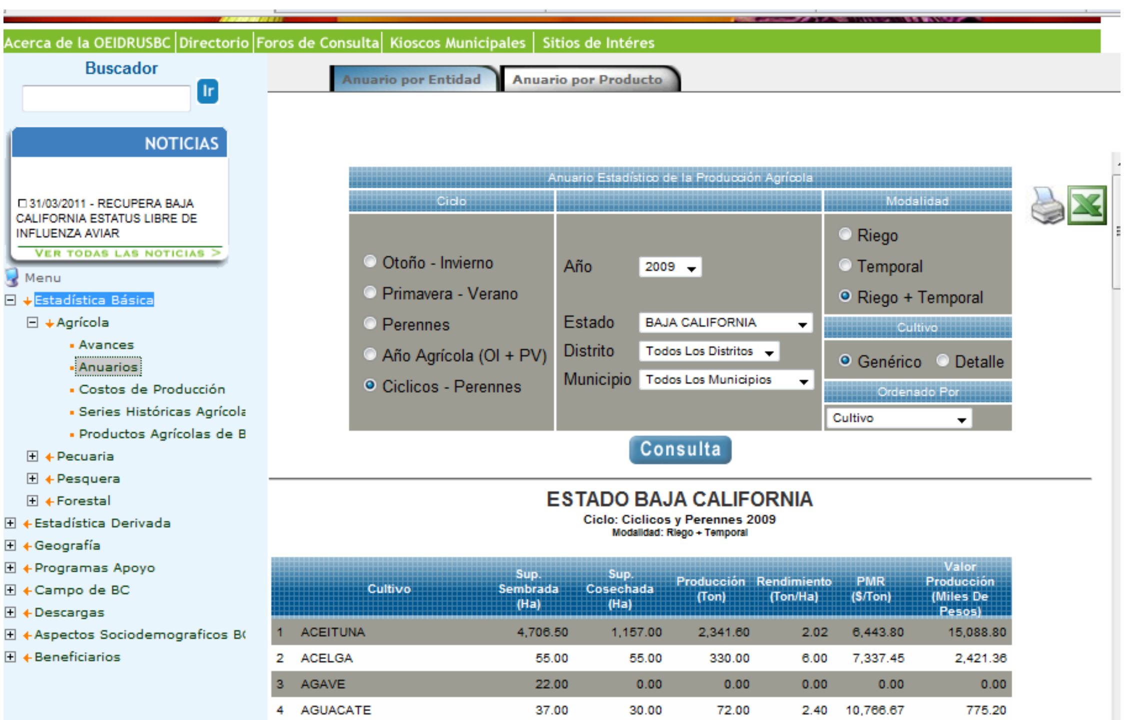
This section, similar to the preceding section on western Colorado, shows step-by-step calculations of the NRTW for two major crops in the Mexicali area, Durum wheat and cotton. It is useful to have another example because certain aspects of the data needed are accessed in a different format than for Yuma County, Arizona and western Colorado. For the Mexicali area, we devote significant attention to how to locate necessary data. However, the calculation steps are the same as the western Colorado example, and the reader should refer back to the previous section for more details. Refer to Table 1 for terminology and definitions used in this section, to Appendix G for acronyms and bilingual glossary, and to Appendix H for conversion tables for unit of measurement.

A group appointed by the Mexican government called the Commission for Technical Assistance for Agriculture, Livestock and Forestry of the State of Baja California (la Comisión para la Asistencia Técnica, Agropecuaria y Forestal del Estado de Baja California) maintains crop budgets for major crops through a governmental website. The website is managed by the state's Office of Information for Sustainable Rural Development (Oficina Estatal de Información para el Desarrollo Rural Sustentable, OEIDRUS). OEIDRUS offers a wealth of annual data on hectares planted, hectares harvested, production (in metric tons), yield (metric tons per hectare), average annual price per metric ton, and total value of production (in thousands of MXN), per crop and per region.[9] The International Maize and Wheat Improvement Center (CIMMYT) provides a similar database for Mexico by crop and by state, but not by region, so while CIMMYT can be considered a valuable resource for data as well, we focus on the OEIDRUS database because of the inclusion of district level data.

To access the data for Baja California, consult the following steps (and refer to Figure 4):

1. Utilize the URL that follows: http://www.oeidrus-bc.gob.mx/oeidrus_bca/.
2. Select *Estadística Básica*.
3. Select *Agrícola*.
4. Select *Anuarios*.
5. Follow the prompts to search within the database. The data can be exported to excel by selecting the *Consulta* button and then the Excel icon.

Figure 4. OEIDRUS database for crop production



To access the crop budgets for Baja California for wheat and cotton, consult the following steps:

1. Begin with the main OEIDRUS website for Baja California, http://www.oeidrus-bc.gob.mx/oeidrus_bca/.

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[9] Within the Mexicali Valley data, the measurement ton refers to a metric ton, equal to 2,204.62 pounds. Refer to Appendix H for the complete conversion table for unit of measurement.

2. Select the appropriate link for either *Sistema Producto Trigo* (for wheat) or *Sistema Producto Algodon* (for cotton).
3. Position cursor over the arrow to the right of the tab titled *Producción*. Highlight *Producción Primaria* and then select *Costos*.

After accessing the crops budgets, begin the NRTW calculation. Follow the steps outlined in western Colorado section for updating cost data in the crop budgets. Refer to Appendix D for a detailed version of the Mexicali crop budgets. Refer to tables 8 and 9 for the NRTW for Durum wheat and cotton, respectively, in Mexicali. The tables were compiled by the authors using primary data for the Mexicali Valley from the OEIDRUS website for Baja California and from SAGARPA. The values in tables 8-9 were adjusted for inflation using the INPC (Índice Nacional de Precios al Consumidor, equivalent to the United States' CPI) to April 2011 MXN, and then converted to USD using the April 2011 exchange rate (Oanda 2011).

To calculate the gross revenues from production, it may be helpful to use the layout of the crop budget for irrigated corn from western Colorado section (Table 6). Unlike the western Colorado example, data needs to be collected manually for the gross revenues for the Mexicali crop budgets. Utilize the database from the OEIDRUS website to obtain the data necessary to calculate the gross revenues. However, data from OEIDRUS is aggregated and averaged over multiple farms of various sizes, so farm-specific data is more accurate and therefore preferred when available.

1. Within the OEIDRUS database, search by the appropriate year and district. For the data in Tables 8 and 9, the district *Río Colorado* was selected.
2. Obtain a value for the average market price per metric ton. In the case of the crop budgets used in this example, the year was either 2007-2008 (for wheat) or 2008-2009 (for cotton). Therefore, an average price was taken for the two years of the period.
3. Obtain a value for the yield (metric tons per hectare). Similar to the price per metric ton, the yields were also averaged over two years for the wheat and cotton crop budgets for this example. More accurate farm-level, *ejido*-level, or irrigation module-level yield data may also be obtained through contact with agronomists, agricultural extension agents or farmers.
4. Multiply market price per metric ton by yield. The value obtained is the gross revenues from production.

To finish the NRTW calculation, proceed with the following steps.

1. Subtract out the fixed costs, which are listed under the miscellaneous (or *diversos*) category, and include itemized costs such as technical assistance, crop insurance and interest. Also subtract out the cost of water. The value that remains is the Variable Costs per hectare (minus the cost of water), which is $8217.78 MXN for wheat and $15339.59 MXN for cotton.
2. Take the gross revenues from production minus the variable costs (minus the cost of water). For wheat, the calculation is $15112.20 MXN - $8217.78 MXN = $6894.42 MXN. For cotton, the calculation is $17073.23 MXN - $15339.59 MXN = $1733.65 MXN. The difference is the NRTW for wheat and cotton in the Mexicali Valley.
3. Locate the cubic meters per hectare of water consumed. Refer to sources listed in the western Colorado section or contact agronomists from the Universidad Autonóma de Baja California (UABC) or SAGARPA employees. The consumptive use figures used in Tables 8 and 9 were obtained from SAGARPA (Carrillo 2009).
4. Divide the NRTW by the cubic meters per hectare of water consumed. The resulting value is the NRTW per cubic meters per hectare of water consumed, or $1060.68 MXN and $194.79 MXN for wheat and cotton, respectively. For this exercise, 1,000 cubic meters per hectare of water consumed was selected as the unit of measurement to facilitate the comparison among crop budgets, though the actual unit of measure used for quantifying the volume of water may depend upon legal requirements for a given region.
5. For conversion to acres and acre-feet: The gross revenues, variable costs and NRTW were multiplied by 0.4046 to convert from hectares to a per acre value. The consumptive use of water was converted from 1,000 cubic meters per hectare to acre-feet per acre by dividing the respective value (6.50 or 8.90) by 3.048.

It is interesting to compare the NRTW in Yuma County with the value for the same crop in the Mexicali Valley, given geographic proximity, similar supply chains, roughly equivalent climatic conditions, and the reliance upon the Colorado River for irrigation water in both cases. In the case of Durum wheat, the NRTW for Yuma County is $77.71 USD per acre-foot of water consumed (from Table 2 from the most recent time period), and for the Mexicali Valley, the value is $111.78 USD per acre-foot of water consumed (from Table 8). In the case of cotton, the cotton in the Yuma crop budgets is processed cotton, whereas the cotton in the

Mexicali Valley crop budgets is unprocessed cotton that still contains the seed. Therefore, a direct comparison of the NRTW for cotton is not possible between the two regions, further reaffirming the idea that the NRTW is highly location specific. Additionally, as mentioned early in the guidebook, legal considerations will be different between United States and Mexico. Nonetheless, the process for calculating NRTW is the same across the border. The following section will go into detail regarding risk preferences, providing a more robust understanding for stakeholders about decision making at the farm level.

Table 8. NRTW, Durum Wheat, Mexicali Valley (in April 2011 MXN)

	Unit	Price or Cost/ Unit	Yield Per Hectare	Value or Cost Per Hectare	For Comparison: Value or Cost per Acre (in 2011 USD)	
Gross Revenues from Production	Metric ton	2421.83	6.24	15112.20	USD	522.51
Variable Costs	MXN			8217.78	USD	284.13
Net Returns to Water	MXN			**6894.42**	NRTW USD	**238.38**
1,000 m^3 of water consumptively used per hectare	1,000 m^3			6.50	AF of water consumptively used per acre	2.13
Net Returns to Water in 1,000 cubic meters per hectare	MXN			**1060.68**	NRTW per AF of water consumed	**111.78**

Table 9. NRTW, Cotton, Mexicali Valley (in April 2011 MXN)

	Unit	Price or Cost/ Unit	Yield Per Hectare	Value or Cost Per Hectare	For Comparison: Value or Cost per Acre (in 2011 USD)	
Gross Revenues from Production	Metric ton	4,099.22	4.165	17073.23	USD	590.31
Variable Costs	MXN			15339.59	USD	530.37
Net Returns to Water	MXN			**1733.65**	NRTW USD	**59.94**
1,000 m^3 of water consumptively used per hectare	1,000 m^3			8.90	AF of water consumptively used per acre	2.92
Net Returns to Water in 1,000 cubic meters per hectare	MXN			**194.79**	NRTW per AF of water consumed	**20.53**

Risk Considerations for Crop Portfolios

Agricultural producers encounter a variety of risks including unpredictable weather, changing input and output prices, fluctuating market conditions, and changes in the cost of debt financing and hiring labor (USDA 1997). One strategy for managing overall farm household risk is through off-farm employment for household members. Another risk management strategy is to plant crops on spatially dispersed agricultural lands located in differing microclimates to take advantage of unique growing conditions and harvesting windows (Wilson, Thompson and Cook 1997). Growers can also plant a mix of crops, combine crop and livestock production, and seek alternate farm revenue sources (Jones and Colby 2010). The ideal mix of revenue-producing activities will vary from farmer to farmer depending upon an individual's level of risk-aversion. In this section, we focus on the role of forbearance payments in diversification of farm revenue-producing activities. Refer to Table 1E in Appendix E for a table that defines terminology related to risk.

"Risk-aversion" is a way of classifying how people make choices when faced with various uncertain outcomes and the probabilities of those outcomes occurring. Suppose that a risk neutral farmer is offered two choices: Option 1) an annual net income of $500,000, or Option 2) a 50-50 chance of earning either $1,000,000 or zero net income. A risk neutral farmer will have no preference between these two options because, by definition, a risk neutral decision maker only considers "expected value" when making decisions. The expected value is the sum of the values of each outcome multiplied by the probability of that outcome.

> ***Example***. The expected value of Option 2 (above) is 0.50 x $1,000,000 + 0.50 * $0 = $500,000.

In contrast, a risk averse farmer presented with these two options would choose the first option, a guarantee of $500,000. Moreover, a risk averse farmer would willingly accept some amount less than $500,000 rather than accept the risky option (Option 2) which has an expected value of $500,000.

In agricultural production, farmers consider variance in net income produced by a crop portfolio, in addition to the expected value of that net income. A risk averse farmer prefers a portfolio with less variance in net income. Variance can be thought of as the extent of positive and negative deviation from the mean (defined in Appendix E). Often, the least risky activities with lower variance do not provide the greatest expected returns. Therefore, a grower can seek to engage in a mix of activities that balances expected return with the variance associated with the return. The mix of activities may include receiving payments for fallowing irrigated cropland so that the water can be used elsewhere. In cases where farmers have opportunities to participate in temporary irrigation forbearance programs, fallowing generates revenues with different risk characteristics from crop revenues. This section of the guidebook explores a variety of crop portfolio arrangements from Yuma County, Arizona, with the addition of fallowing as a crop in the portfolio.

Financial portfolio management is a popular subject which encompasses a wide range of risk-reducing strategies. The basic idea is to select a mix of assets that are diverse in level of risk. Portfolios will differ from person to person, dependent upon one's level of risk aversion and financial goals. Crop portfolios are similar to financial portfolios, yet face a different set of complexities. For instance, Lavee (2010) found that in Israel, water supply uncertainty affects crop portfolio diversification and farmers were less likely to invest in multi-seasonal crops due to uncertainty about water availability.

The field of agricultural risk management focuses broadly on many types of farm household income, costs and assets. Recent studies have shown that changing land values may have a greater impact on farmers' crop choices than crop prices (Barnett and Coble 2009). Yet, due to the focus in this guidebook on agricultural water use, this section of the guidebook emphasizes risk management in irrigated crop production. Although growers may intuitively understand how to reduce risk through crop diversification based upon years of experience, agricultural economists look at diversification and overall risk reduction systematically. Risk in net revenues can be addressed by strategically combining revenue-producing activities that are correlated with one another to varying degrees. Calculating correlations is helpful in this context because it enables stakeholders to make informed decisions based upon numerical values.

Ideally, a grower will identify ways to combine negatively correlated revenue-producing activities to achieve the greatest reduction in variability of net farm income (Sonka and Patrick 1984). "Negatively correlated" implies that one activity becomes more profitable under circumstances which make another revenue-producing activity less profitable. For instance, an early summer heat wave may reduce yields and net revenues for one particular crop, but increase yields and earnings from another crop. A grower will aim to select a variety of crops that are impacted differently by external forces. This can be hard to achieve in a crop mix, as crop yields tend to be affected by the same forces such as frost, drought and other regional conditions. Although it may be difficult to find crops that are negatively correlated, combining positively but weakly correlated activities can also reduce variability in farm net income. Forbearance payments to growers, paid for temporary use of their water, typically are uncorrelated with net returns from crop production. Consequently, water acquisition can be a means for reducing overall variability in farm net income.

Crop Net Income Correlations. A correlation of 1.0 indicates that net incomes from the two crops are perfectly correlated (net incomes rise and fall identically). A correlation close to zero indicates that the two net incomes vary in a manner completely unrelated to one another. A negative correlation indicates that as net income from one crop rises, the net income from the other crop declines – that is, they move in opposite directions. A correlation of -1.0 between net incomes from a farm's key crops would be ideal in balancing risk, but is unlikely. A correlation closer to zero is more realistic and still beneficial in reducing risk.

Table 10 shows gross revenues per acre for alfalfa, Upland cotton, Durum wheat and head lettuce for Yuma County, Arizona from 2000-2008 and Table 11 shows crop revenue variation in terms of the coefficient of variation (Jones and Colby 2010). Coefficient of variation, which is a standard measure of riskiness, measures the variation in a given variable as a ratio of the standard deviation to the mean and is calculated as a percent (Jung, Shambora and Choi 2010). A high value indicates greater variation around the mean (and a higher level of risk) and a value close to zero indicates a little variation around the mean (and a lower level of risk). In Table 11, we see that lettuce has a much higher coefficient of variation than Upland cotton, for instance. Table 12 shows crop revenue correlations, where crop revenues are a function of price and yield (Jones and Colby 2010).

The coefficient of variation and the crop revenue correlations are the only two quantifiable measures of risk that we explore in this section of the guidebook. Other factors, in addition to level of risk-aversion, contribute to a farmer's decision of whether or not to plant a crop with a greater potential for high returns. Farmers, for instance, may want to grow a crop with high returns (such as lettuce) but be unable to do so because of barriers to accessing specialized markets for that crop. Other barriers for crop diversification may be access to appropriate machinery, specialized management skills, and seasonal labor availability.

Table 10: Gross Revenues for Selected Crops, Yuma County, Arizona (in USD)

	Yuma County, Arizona									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	AVG
					Hay Alfalfa					
Acres Harvested	30000	31500	32000	31000	28000	28000	21500	25000	25000	28000
Yield/Acre (tons)	8.7	8.3	8.6	9.7	10.0	9.1	9.1	9.4	9.8	9.2
Price/Ton ($)	94.00	99.00	100.00	89.50	99.50	124.00	128.00	151.00	186.00	119.00
Gross Revenues/ Acre ($)	814.98	816.75	862.00	866.36	995.00	1129.64	1160.96	1419.40	1822.80	1098.65
					Cotton, Upland					
Acres Harvested	25300	25500	17900	24500	26700	27300	21900	16800	9800	21744
Yield/Acre (lbs)	1385	1129	1397	1254	1438	1213	1315	1457	1420	1334
Price/lb ($)	0.40	0.28	0.46	0.66	0.44	0.52	0.53	0.60	0.57	0.50
LDP/lb ($)*	0.04	0.30	0.14	0.04	0.13	0.15	0.09	0.00	0.00	0.10
Gross Revenues/ Acre ($)	610.81	654.12	847.29	887.80	829.81	805.62	813.71	868.37	809.40	791.88
					Wheat, Durum					
Acres Harvested	38600	36400	44300	46000	42500	36300	35000	36200	43100**	40050
Yield/Acre (bushels)	101.7	95.8	96.5	102.7	100.0	103.0	106.0	107.0	107.3**	102.5
Price/Bushel ($)	3.50	3.95	4.40	4.65	4.25	4.20	4.85	7.11	8.30	5.39
Gross Revenues/ Acre ($)	355.94	378.64	424.70	477.40	425.10	432.60	514.21	760.77	890.70	560.78
					Lettuce, Head					
Acres Harvested	50300	51800	50000	49600	46500	49600	47600	39900	32700	46444
Yield/Acre (cwt)	350.0	365.0	350.0	360.0	360.0	325.0	330.0	365.0	360.0	351.7
Price/cwt ($)	13.10	16.50	38.70	10.30	22.20	14.60	14.10	21.00	15.80	18.48
Gross Revenues/ Acre ($)	4585.00	6022.50	13545.00	3708.00	7992.00	4745.00	4653.00	7665.00	5688.00	6511.50

*LDP: Loan Deficiency Payments are a form of US price support. Farmers may request and receive LDP when cotton price falls below an established minimum.**2008 Acres Harvested & Yield/Acre unavailable for Wheat, Durum at county level. Average of 2007 and 2009 values used.

Table 11: Crop Revenue Coefficient of Variation

Yuma County	Standard Deviation	CV
Hay Alfalfa	337.78	31%
Cotton, Upland	95.06	12%
Wheat, Durum	183.65	33%
Lettuce, Head	3001.15	46%
CV, the coefficient of variation, is calculated by dividing the standard deviation of each crop by its mean. The ratio is then multiplied by 100. See Appendix E for a full explanation of the calculation.		

Table 12: Crop Revenue Correlations

	Yuma Crop Correlations				
	Alfalfa	Cotton	Wheat	Lettuce	Fallow
Alfalfa	1.00				
Cotton	0.35	1.00			
Wheat	0.95	0.43	1.00		
Lettuce	-0.11	0.26	-0.04	1.00	
Fallow	0.91	0.60	0.86	-0.12	1.00
The payment for fallowing used in the portfolio analysis comes from the average per acre payment in the PVID-MWD agreement (Palo Verde Irrigation District – Metropolitan Water District 2004). The payment started in 2005 and escalates by 2.5% each of the first five years. Since payments were not available for years prior to 2005, the payment was assumed to be 2.5% less for each preceding year, compounding annually.					

Tables 10 and 11 show that head lettuce has the highest average gross revenues per acre of $6511.50 USD. However, when viewing the coefficient of variation as an indicator of risk, lettuce is the riskiest among the four crops, at 46%. Alfalfa, on the other hand, has a lower average gross revenue per acre of $1,098.65 USD, but is relatively less risky with a coefficient of variation of 31%. This implies that although head lettuce provides the highest average gross revenue per acre, a risk-averse grower may wish to reduce head lettuce acreage in favor of an alternative crop or income source that exhibits less variability. Also, a farmer might use the coefficient of variation to assist in the selection of a range of crops with varying levels of riskiness for a crop portfolio.

Choosing crop mixes with a range of crop correlations is another method for varying the level of risk in a crop portfolio. Using Yuma County data from Table 10, Table 12 shows crop correlations, with a range from -.12 to .95. Wheat and alfalfa revenues are highly, but not perfectly, correlated at .95, so a wheat-alfalfa portfolio would not be very effective at reducing risk. A wheat-head lettuce portfolio would be more effective as the correlation is -.04. Initially it appears that a wheat-fallowing portfolio, with a correlation of .86, would be less effective than a wheat-head lettuce portfolio at reducing risk. However, it is important to understand that the correlation between wheat and fallowing payments is incidental and was the result of both increasing (for differing reasons) over the time period analyzed. The implication for risk management strategies is that under certain conditions, a wheat-fallowing combination can contribute to a reduction in risk. Tables 11 and 12 consider only two of many risks which can affect net revenues from crop production, the risk of changes in the price farmers receive for crops they produce and risk associated with changes in yield per acre.

While the above example describes a simple two-crop portfolio, alternative multi-crop portfolios may be conceived which will further reduce risk. Included in that portfolio may be other crops (not mentioned in Tables 10, 11 and 12), as well as fallowing payments.

If a grower is seeking to diversify her crop portfolio, then she may be responsive to offers to refrain from irrigation in return for a payment. While NRTW represents a theoretical minimum payment that is required to acquire irrigation water, a grower may actually accept a lower payment because the fallowing payment to be received is guaranteed through a contract with the party seeking to use the water, and likely entails less risk than producing crops. In forbearance programs around the western U.S., payments to growers have often substantially exceeded the NRTW. This occurs where the agricultural water users have strong bargaining power in negotiations, where the value of senior agricultural water to the purchaser is high, and for a variety of other reasons.

In some situations, reading this section of the guidebook and the information in Tables 10, 11, and 12 may suffice for giving readers a satisfactory understanding of the role of risk in crop portfolios. However, if the reader has an interest in calculating the crop correlations and coefficient of variation for a specific region and/or time period not included in this guidebook, please refer to Appendix E for calculation instructions.

Understanding factors that impact farm-level decision-making is useful for stakeholders who are assessing the value of water in agriculture and considering in temporary water transfer negotiations. Farmers and water buyers alike will benefit from a broader sense of the risks involved in irrigated crop production. In addition, it may be beneficial for regional water managers to understand the many factors that play a role when farmers consider tradeoffs between different crops, as these decisions also impact overall agricultural water use. Parties seeking to temporarily acquire water from growers should consider including a discussion of the farm income portfolio and risk considerations when presenting their offers to growers and irrigation districts.

Adjusting Payments Over Time in Multi-Year Agreements

Parties negotiating temporary water acquisitions need to consider including a method by which the payment to growers will be adjusted over time. Agreements to use agricultural water may extend over multiple years, even when the use is temporary and intermittent, such as with dry-year options where the transfer to another use is triggered by water shortage conditions. (For more information on contingent water contracts, refer to an earlier guidebook in this series titled "Dry-year Water Supply Reliability Contracts: A Tool for Water Managers.")[10] In multi-year agreements, some method of adjusting payments over time is important to the stability of the agreement. If a notable discrepancy develops between the price being paid under the agreement and perceptions of the value of water in the region, then parties may seek to dissolve the agreement, creating costs and conflicts. For instance, if crop prices increase and crop irrigation becomes more profitable than when the agreement was signed, participation may no longer be attractive to farmers. On the other hand, if a regional economy takes a downturn and economic activity slumps, the price negotiated may seem too high and urban purchasers may seek to de-stabilize the agreement.

To avoid future conflicts spurred by such economic changes, the transaction agreement should specify a method to adjust the per unit payments made for use of water over the years of the agreement. The index should be based on publically observable factors that are not directly under the control of parties to the transaction. One simple option is to adjust payments based on the Consumer Price Index in order to keep pace with inflation. Regional CPI tables exist for multiple areas across the United States, and an appropriate region may be specified in the agreement.

Other regionally specific indexes may be utilized as well. Water transactions in the western U.S. have been shown to rise and fall with urban housing values (Basta and Colby 2011). The payment per unit of water provided through fallowing could be adjusted annually based on the Federal Housing Finance Agency (FHFA) Housing Price Index (HPI), for instance. The HPI is released quarterly, and is compiled by the FHFA for single unit residential houses based upon a weighted average of sales and refinancing events (FHFA 2011). Changes in the HPI for a nearby urban area could be used to adjust water payments for fallowing on an annual basis. Use of a housing value index links forbearance payments to economic changes in the regional economy.

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[10] Located on the University of Arizona Agricultural and Resource Economics Department website at http://ag.arizona.edu/arec/people/profiles/colby.html

A different adjustment method is to focus upon changes in agricultural profitability. The U.S. Department of Agriculture produces an annual index of Producer Prices Received and Producer Prices Paid for all agricultural commodities in the United States (USDA NRCS 2011). The ratio of Producer Prices Received Index divided by Producer Prices Paid Index gives a general indicator of changes in farm profitability. In cases where more specificity is desired, the calculations of NRTW used in initially developing a price agreement can be recalculated annually for the region using updated crop prices, yields and inputs costs. The resulting updated NRTW can be used to adjust payments for water.

Regardless of the complexity of the adjustment method selected, the principle of providing for annual adjustments in payments is important to the stability of multi-year irrigation forbearance agreements.

Summary: Tools for Price Negotiations in Water Acquisitions

Potential participants in water transactions will find it a useful preparation for negotiation to estimate the current value of water used to grow crops by calculating NRTW, and examine the fluctuations in NRTW over recent years. Additionally, consideration of managing risk in farm net income may assist in water negotiations. Growers may be more apt to participate in water transactions after discussing ways in which income from water transfers can help to diversify their farm income portfolios. Agreeing upon a method for adjusting payments over time is another crucial step in ensuring stable contracts. Armed with a better understanding of the value of water in agriculture, and given that growers are often interested in portfolio diversification and in the long-term stability of a contract, a prospective water buyer can more effectively participate in water transfer negotiations. Effective preparation can reduce the likelihood of overpayment while increasing the likelihood of a successful negotiation to acquire water. Below are several suggestions for structuring price negotiations in water acquisitions involving temporary use of water normally used for crop irrigation.

1) Structure the transaction to focus on reduced units of water consumptive use, rather than on cropland acres fallowed or water quantities diverted.

2) Correctly identify the volume of reduced consumptive use that is associated with each acre of irrigated cropland proposed for temporary fallowing. This typically involves verifying several years of crop production on the specific parcels to be fallowed, and identifying the most up-

to-date crop consumptive use figures available for the area. (Refer to Appendix F for additional information on calculating crop consumptive use of water).

3) Prepare an estimate of the NRTW per acre-foot consumed for the crops grown on the parcels proposed for fallowing. This estimate should be based on three to five years of data for crop yields, crop prices and input costs, to prevent unusual conditions in one particular year from dominating the analysis.

4) Request comment on the NRTW estimates from the parties to the transaction and incorporate additional information specific to the parcels involved.

5) Use the revised NRTW as a baseline in negotiating the price per unit of water to be provided through cropland fallowing. For instance, an offer could be phrased as "two times the NRTW for the crop mix grown over the past three years on the parcels to be fallowed."

6) If the agreement is to extend over multiple years, agree upon a method to adjust the payments made for use of water over the years of the agreement.

This guidebook covers just one of several topics relevant to water acquisitions that are discussed in an ongoing series of guidebooks. This series is intended to assist public agencies, non-profit organizations, irrigation districts, local governments and the private sector with design and implementation of water acquisition programs to improve water supply reliability during drought and under climate change.

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Appendix A: Sources for Crop Budgets

Crop budgets can be located on many cooperative extension websites of land-grant universities. Land-grant universities are a category of higher education institutions in the United States that were created through legislation passed in the mid to late 1800's. One of the major goals of these public universities is to focus on improving agriculture and therefore they are centers for agricultural research and cooperative extension. A map of all of the land-grant universities in the United States can be located at the USDA National Institute of Food and Agriculture (formerly known as Cooperative State Research, Education and Extension Service, or CSREES) website http://www.csrees.usda.gov/qlinks/partners/partners_map.pdf.

The Ag Risk Education Library website also has many websites with crop budgets by state and can be located at http://www.agrisk.umn.edu/Budgets/StateWebsites.aspx. This website is jointly sponsored by the U.S. Department of Agriculture Risk Management Agency and the University of Minnesota.

The crop budgets used in this paper are located on the websites of the University of Arizona Department of Agricultural and Resource Economics and the Colorado State University Agriculture and Business Management respectively, as follows:

http://ag.arizona.edu/arec/extension/budgets.html

http://www.coopext.colostate.edu/abm/cropbudgets.htm

Crop budgets in Mexico may be located by state on the governmental website managed by Office of Information for Sustainable Rural Development (Oficina Estatal de Información para el Desarrollo Rural Sustentable, OEIDRUS). The crop budgets used for Mexicali Valley were obtained from the following website:

http://www.oeidrus-bc.gob.mx/oeidrus_bca/

Appendix B. Crop Budgets for Yuma, Arizona

The tables below show calculations of NRTW for alfalfa, Durum wheat, Upland cotton and head lettuce in Yuma County Arizona. With the exception of Upland cotton, each table contains five-year highs and lows for prices and yields for the period 2005-2009, five-year averages for the same period, and prices and yields for the most recent year, 2009. The table for Upland cotton shows the same except the period is three years, 2006-2008. Each table also includes gross revenue per acre, variable costs per acre (excluding water costs), NRTW per acre, the estimated volume of water required to grow each crop, respectively, and finally the NRTW per acre-foot of water consumed.

NRTW calculations below are based on costs from University of Arizona crop budgets (Teegerstrom and Knowles 1999; Teegerstrom and Tickes 1999; Teegerstrom, et al. 2001) updated using USDA producer cost indices (USDA 2010). All chemical input prices were updated through personal communication with chemical input suppliers. Yields and commodity prices come from Arizona Agricultural Statistics Bulletins (USDA 2005; 2006; 2007; 2008; 2009; 2010). Crop consumptive water use was obtained from LCRAS annual water use figures (Bureau of Reclamation 2002-8). Numbers in parentheses represent negative values. All prices are adjusted to April 2011 USD (US Bureau of Labor 2011).

Yuma Durum Wheat (in April 2011 USD)	**2009**	**5yr Avg (05- 09)**	**High**	**Low**
<u>Revenue per Acre</u>				
Yield/acre	107.5	106.1	107.5	103
Price/bushel	$8.61	$6.68	$8.61	$4.49
Gross Revenue ($/Acre)	$925.79	$710.41	$925.79	$462.43
Variable Costs per Acre	$560.75	$560.75	$560.75	$560.75
Net Returns to Water Per Acre	$365.04	$149.66	$365.04	($98.32)
AF water consumptively used per acre	1.9	1.9	1.9	1.9
Net Returns to Water Per Acre-foot of water Consumed	$192.13	$78.77	$192.13	($51.75)

Yuma Alfalfa Production (in April 2011 USD)	2009	5yr Avg (05- 09)	High	Low
Revenue per Acre				
Yield/acre	9.05	9.29	9.8	9.05
Price/ton	$118.73	$143.47	$179.32	$118.73
Gross Revenue ($/Acre)	$1,074.41	$1,338.08	$1,757.97	$1,074.41
Variable Costs per Acre	$601.96	$601.96	$601.96	$601.96
Net Returns to Water Per Acre	$472.45	$736.12	$1,156.01	$472.45
AF water consumptively used per acre	5.5	5.5	5.5	5.5
Net Returns to Water Per Acre-foot of water Consumed	$85.90	$133.84	$210.18	$85.90

When the tables were compiled, the most recent data for Yield/acre (lint) was from 2008 and the most recent data for Yield/acre (seed) was from 2006; thus, the table spans the years 2006-2008. LDP are not applicable unless county cotton prices fall below the loan rate set by the Farm Service Agency, and were only available in 2006 (USDA FSA 2010). The NRTW calculation is the same as the other crops, except the LDP is added as another source of revenue in the gross revenue calculation.

Yuma Upland Cotton (in April 2011 USD)	2008	3yr Avg (06-08)	High	Low
Revenue per Acre				
Yield/acre (lint)	1420	1397	1420	1315
Price/pound (lint)	$0.57	$0.57	$0.60	$0.55
LDP/pound	$0.00	$0.03	$0.00	$0.09
Yield/acre (seed)	1.05	1.05	1.05	1.05
Price/ton (seed)	$276.35	$214.88	$276.35	$172.94
Gross Revenue ($/Acre)	$1,095.65	$1,024.99	$1,095.65	$1,020.42
Variable Costs per Acre	$1,270.03	$1,270.03	$1,270.03	$1,270.03
Net Returns to Water Per Acre	(174.38)	(245.04)	(174.38)	(249.60)
AF water consumptively used per acre	3.50	3.50	3.50	3.50
Net Returns to Water Per Acre-foot of water Consumed	(49.82)	(70.01)	(49.82)	(71.32)

Yuma Head Lettuce (in April 2011 USD)	2009	5yr Avg (05- 09)	High	Low
Revenues per Acre				
Yield/acre	345	342	345	325
Price/cwt	$22.28	$17.80	$22.06	$14.61
Gross Revenue ($/Acre)	$7,688.06	$6,116.87	$7,688.06	$4,745.44
Variable Costs per Acre	$3,442.14	$3,442.14	$3,442.14	$3,442.14
Net Returns to Water Per Acre	$4,245.92	$2,674.73	$4,245.92	$1,303.31
AF water consumptively used per acre	1.3	1.3	1.3	1.3
Net Returns to Water Per Acre-foot of Water Consumed	$3,266.09	$2,057.48	$3,266.09	$1,002.54

Accurate variable costs data is an important component of calculating net returns to water. The tables below illustrate the type of data involved and actual variable cost figures for specific crops in Yuma County, Arizona. Note the details provided on the annual timing of various crop production operations. This type of information is helpful in determining the best point in the year to ask growers to stop irrigating in a forbearance program. Ideally, the request will occur when little or no costs have already been invested in growing a crop that will not be harvested due to forbearance. In the alfalfa table of itemized variable costs only, the month indicated represents the first month in which that operation takes place during the calendar year. The number of times the operation is performed is not limited to the first month (the month listed in the table) but instead is dispersed throughout the year at regular intervals.

The variable cost figures below are based upon University of Arizona crop budgets (Teegerstrom and Knowles 1999; Teegerstrom and Tickes 1999; Teegerstrom, et al. 2001) and were updated to 2010 USD using USDA Producer Prices Paid Index (PPPI) (USDA NRCS 2010). All chemical input prices were updated through personal communication with chemical input suppliers. All prices were then adjusted to April 2011 USD (US Bureau of Labor 2011).

County:			**Yuma**				
Crop:			**Alfalfa**				
Variable Costs:			**$601.96 USD**				
Month	**# of Times Operation Performed**	**Operations**	**Class**	**Cost**	**Running Total (USD)**	**% of Total Variable Cost**	**Running Total (%)**
Jan	16	Irrigate	Growing	56.82	56.82	9.4%	9.4%
Jan	9	Swathing	Harvest	79.68	136.50	13.2%	22.7%
Jan	9	Raking	Harvest	37.51	174.01	6.2%	28.9%
Jan	9	Bailing	Harvest	162.27	336.28	27.0%	55.9%
Jan	9	Roadsiding	Harvest	86.98	423.27	14.4%	70.3%
Feb	4	Rerun Borders	Growing	14.90	438.16	2.5%	72.8%
Feb	1	Apply Herbicide/Ground	Growing	33.63	471.79	5.6%	78.4%
Mar	1	Apply Insecticide/Air	Growing	31.08	502.88	5.2%	83.5%
Sep	1	Irrigate/Run Fertilizer	Growing	22.09	524.97	3.7%	87.2%
Oct	0.3	Renovate	Growing	2.34	527.31	0.4%	87.6%
Oct	0.3	Plant	Land Prep	18.28	545.59	3.0%	90.6%
Misc.		Pickup Use		29.99	575.58	5.0%	95.6%
		Operating Interest		26.38	601.96	4.4%	100.0%
TOTAL				**601.96**	601.96	**100.0%**	100.0%

County:		**Yuma**				
Crop:		**Upland Cotton**				
Variable Costs:		**$1,270.03 USD**				
Month	**Operations**	**Class**	**Cost**	**Running Total (USD)**	**% of Total Variable Cost**	**Running Total (%)**
Dec	Rip	Land Prep	14.83	14.83	1.2%	1.2%
Dec	Disk	Land Prep	17.78	32.60	1.4%	2.6%
Jan	Laser Level	Land Prep	50.54	83.15	4.0%	6.5%
Jan	Roll Beds	Growing	3.26	86.40	0.3%	6.8%
Jan	List	Land Prep	9.60	96.00	0.8%	7.6%
Feb	Preirrigate	Growing	6.16	102.16	0.5%	8.0%
Mar	Mulch	Land Prep	7.62	109.78	0.6%	8.6%
Mar	Plant	Land Prep	10.88	120.65	0.9%	9.5%
Mar	Remove Cap	Growing	6.21	126.87	0.5%	10.0%

Apr	Cultivate	Growing	28.58	155.44	2.3%	12.2%
Apr	Soil Fertility	Growing	2.89	158.33	0.2%	12.5%
May	Irrigate/Run Fertilizer	Growing	72.62	230.95	5.7%	18.2%
Jun	Irrigate	Growing	6.16	237.11	0.5%	18.7%
Jun	Hand Weeding	Growing	96.35	333.45	7.6%	26.3%
Jun	Apply Insecticide/Ground	Growing	43.83	377.28	3.5%	29.7%
Jun	Apply Herbicide/Ground	Growing	11.76	389.04	0.9%	30.6%
Jul	Apply Insecticide/Ground	Growing	192.82	581.86	15.2%	45.8%
Jul	Apply Insecticide/Ground	Growing	14.35	596.21	1.1%	46.9%
Jul	Hand Weeding	Growing	96.35	692.55	7.6%	54.5%
Jul	Apply Insecticide/Air	Growing	14.35	706.90	1.1%	55.7%
Aug	Apply Insecticide/Air	Growing	12.20	719.09	1.0%	56.6%
Aug	Apply Insecticide/Air	Growing	15.58	734.67	1.2%	57.8%
Aug	Irrigate/Run Fertilizer	Growing	64.57	799.24	5.1%	62.9%
Sep	Apply Insecticide/Air	Growing	15.95	815.19	1.3%	64.2%
Sep	Apply Defoliant/Air	Harvest	42.82	858.01	3.4%	67.6%
Sep	Apply Defoliant/Air	Harvest	25.08	883.08	2.0%	69.5%
Sep	Dust Control	Growing	29.34	912.42	2.3%	71.8%
Sep	Prepare Ends	Harvest	1.65	914.07	0.1%	72.0%
Sep	Cotton, First Pick	Harvest	77.08	991.15	6.1%	78.0%
Sep	Cotton, Make Mounds	Harvest	16.98	1008.12	1.3%	79.4%
Sep	Cotton, Rood	Harvest	41.75	1049.87	3.3%	82.7%
Sep	Haul	Harvest	6.55	1056.42	0.5%	83.2%
Sep	Cotton Ginning	Post Harvest	108.55	1164.97	8.5%	91.7%
Dec	Cotton Classing	Marketing	3.18	1168.15	0.3%	92.0%
Dec	Crop Assessment	Marketing	9.04	1177.19	0.7%	92.7%
Dec	Cut Stalks	Post Harvest	6.44	1183.62	0.5%	93.2%
Dec	Disk Residue	Land Prep	18.10	1201.73	1.4%	94.6%
Misc.	Pickup Use		35.99	1237.71	2.8%	97.5%
	Operating Interest 6%		32.31	1270.03	2.5%	100.0%
TOTAL			**1270.03**	**1270.03**	**100.0%**	**100.0%**

County:		Yuma				
Crop:		Durum Wheat				
Variable Costs:		$560.75 USD				
Month	**Operations**	**Class**	**Cost**	**Running Total (USD)**	**% of Total Variable Cost**	**Running Total (%)**
Dec	Disk	Land Prep.	60.85	60.85	10.9%	10.9%
Dec	Roll Beds	Land Prep.	3.26	64.11	0.6%	11.4%
Dec	Laser Level	Land Prep.	41.31	105.42	7.4%	18.8%
Dec	Apply Fert/Ground	Growing	101.45	206.87	18.1%	36.9%
Dec	Plant	Land Prep.	35.65	242.52	6.4%	43.2%
Jan	Make Borders	Growing	3.14	245.66	0.6%	43.8%
Jan	Irrigate	Growing	4.93	250.59	0.9%	44.7%
Feb	Apply Herb/Ground	Growing	28.49	279.08	5.1%	49.8%
Feb	Irrigate/Run Fert	Growing	113.65	392.73	20.3%	70.0%
Feb	Apply Herb/Ground	Growing	24.39	417.13	4.4%	74.4%
Mar	Apply Insect/Air	Growing	16.71	433.83	3.0%	77.4%
Mar	Irrigate	Growing	9.86	443.69	1.8%	79.1%
Jun	Combine Harvest	Harvest	55.57	499.26	9.9%	89.0%
Jun	Haul	Harvest	15.17	514.44	2.7%	91.7%
Jun	Disk Residue	Land Prep.	18.10	532.54	3.2%	95.0%
Misc.	Pickup Use		18.00	550.54	3.2%	98.2%
Misc.	Op. Interest 6%		10.21	560.75	1.8%	100.0%
TOTAL			**560.75**	**560.75**	**100.0%**	**100.0%**

County:		Yuma				
Crop:		Head Lettuce				
Variable Costs:		$3442.14 USD				
Month	**Operations**	**Class**	**Cost**	**Running Total (USD)**	**% of Total Var. Cost**	**Running Total (%)**
July	Rip	Lnd Prep	27.07	27.07	0.8%	0.8%
July	Disk	Lnd Prep	18.41	45.48	0.5%	1.3%
July	Laser Level	Lnd Prep	26.43	71.91	0.8%	2.1%
July	Make Borders	Growing	0.62	72.53	0.0%	2.1%
July	Preirrigate	Growing	6.16	78.69	0.2%	2.3%
July	Soil Fertility	Growing	2.89	81.58	0.1%	2.4%

July	Dust Control	Growing	5.77	87.35	0.2%	2.6%
Aug	Apply Fert/Ground	Growing	111.20	198.55	3.3%	5.9%
Aug	Apply Herbicide/Ground	Growing	126.35	324.90	3.7%	9.6%
Sep	List	Lnd Prep	7.12	332.02	0.2%	9.8%
Aug	Pre-Shape	Lnd Prep	10.72	342.74	0.3%	10.1%
Aug	Shape Beds	Lnd Prep	23.24	365.98	0.7%	10.8%
Sep	Plant	Lnd Prep	130.31	496.29	3.8%	14.6%
Sep	Bird Control	Growing	5.88	502.16	0.2%	14.8%
Sep	Set Sprinklers	Growing	5.87	508.03	0.2%	15.0%
Sep	Irrigate/Sec Sys	Growing	6.72	514.75	0.2%	15.2%
Sep	Apply Insecticide/Air	Growing	31.32	546.07	0.9%	16.1%
Sep	Field Scouting	Growing	86.71	632.78	2.6%	18.6%
Oct	Apply Insecticide/Ground	Growing	32.58	665.36	1.0%	19.6%
Oct	Apply Insecticide/Ground	Growing	52.93	718.29	1.6%	21.2%
Sep	Irrigate/Run Fertilizer	Growing	22.71	741.00	0.7%	21.8%
Sep	Remove Sprinklers	Growing	5.87	746.87	0.2%	22.0%
Sep	Make Ditches	Growing	3.20	750.07	0.1%	22.1%
Oct	Irrigate/Run Fertilizer	Growing	144.80	894.87	4.3%	26.4%
Oct	Thinning	Growing	96.35	991.21	2.8%	29.2%
Oct	Cultivate	Growing	42.41	1033.62	1.2%	30.5%
Oct	Apply Fungicide/Ground	Growing	50.47	1084.09	1.5%	31.9%
Oct	Apply Insect/Ground	Growing	10.80	1094.89	0.3%	32.3%
Oct	Apply Insect/Air	Growing	32.34	1127.23	1.0%	33.2%
Oct	Irrigate/Run Fertilizer	Growing	44.79	1172.02	1.3%	34.5%
Oct	Hand Weeding	Growing	96.35	1268.37	2.8%	37.4%
Oct	Apply Insect/Ground	Growing	25.63	1294.00	0.8%	38.1%
Nov	Knock Borders	Growing	0.62	1294.61	0.0%	38.1%
Nov	Knock Ditches	Growing	1.07	1295.68	0.0%	38.2%
Nov	Harvest, Load and Haul	Harvest	2088.00	3383.69	61.5%	99.7%
Dec	Disk Residue	Lnd Prep	9.20	3392.89	0.3%	100.0%
Misc.	Pickup Use		29.99	3422.88	0.9%	100.9%
	Operating Interest 6%		19.26	3442.14	0.6%	100.0%
TOTAL			**3442.14**	**3442.14**	**100.0%**	**100.0%**

Appendix C. Crop Budget for Irrigated Corn, Western Colorado

All prices have been updated to April 2011 USD using the CPI (US Department of Labor 2011).

	Unit	Price or Cost/Unit	Quantity	Value or Cost Per Acre	Value or Cost/Unit Production
GROSS RECEIPTS FROM PRODUCTION					
CORN	BU	3.59	171.50	616.32	
TOTAL RECEIPTS				**616.32**	**3.59**
DIRECT COSTS					
Operating Pre-Harvest					
SEED	DOLLARS	46.73	1.00	46.73	0.27
FERTILIZER	DOLLARS	97.12	1.00	97.12	0.57
HERBICIDE (APPLIED)	DOLLARS	31.43	1.00	31.43	0.18
INSECTICIDE	DOLLARS	13.30	1.00	13.30	0.08
IRRIGATION WATER	DOLLARS	24.09	1.00	24.09	0.14
IRRIGATION LABOR	DOLLARS	51.06	1.00	51.06	0.30
CROP INSURANCE	DOLLARS	25.71	1.00	25.71	0.15
CUSTOM APPLICATION	DOLLARS	11.56	1.00	11.56	0.07
CUSTOM AERIAL SPRAY	DOLLARS	7.71	1.00	7.71	0.04
CROP CONSULTANT	DOLLARS	5.78	1.00	5.78	0.03
FUEL	DOLLARS			14.15	0.08
REPAIR & MAINTENANCE	DOLLARS			6.53	0.04
LABOR	DOLLARS			7.27	0.04
INTEREST EXPENSE	DOLLARS			11.99	0.07
IRRIGATION WATER - Subtracted	DOLLARS	24.09	1.00	-24.09	-0.14
Total Preharvest				**330.33**	**2.07**
Operating Harvest					
FUEL	DOLLARS			5.34	0.03
REPAIR & MAINTENANCE	DOLLARS			4.36	0.03
LABOR	DOLLARS			1.44	0.01
HAULING	DOLLARS			28.08	0.16
Total Harvest				**39.22**	**0.23**
Total Variable Costs				**369.55**	**2.30**
NET RETURNS TO WATER				**246.77**	
AF of water consumptively used per acre				1.86	
NRTW per AF of water consumed				**132.67**	

Appendix D. Crop Budgets for Durum Wheat and Cotton, Mexicali Valley

Crop budget for Durum wheat, from 2007-2008, and updated to April 2011 MXN (INCP 2011).

	Units			Cost per ha
	Unit	Quantity	Cost	
Prepare Soil				1420.68
Plow	Machine	1	487.09	487.09
Disk	Machine	2	243.55	487.09
Roll	Machine	1	243.55	243.55
Make Borders	Machine	1	121.77	121.77
Canals & Drainage	Machine	2	40.59	81.18
Planting				885.69
Seed	KGS	180	3.08	555.28
Plant	Machine	1	243.55	243.55
Irrigation and conservation permit	Fee	1	86.86	86.86
Fertilization				3628.17
Ammonium Phosphate 11-52-00	KGS.	150	5.18	776.91
Urea	KGS.	350	4.82	1687.77
Ammonia	KGS.	120	4.71	565.02
10-34-00	KGS.	80	3.93	314.34
Apply fertilizer	Machine	2	121.77	243.55
Spreader	KGS.	500	0.08	40.59
Irrigation				1053.33
Cost of Water	LTS.	117	6.09	712.37
Irrigation	Labor	6	56.83	340.96
Pest and Weed Control				878.79
Dimethoate	LTS.	1.5	77.12	115.68
Post emergence herbicide treatment	Application	1	600.74	600.74
Application of herbicide and	Aerial	1	162.36	162.36
Harvest				1063.48
Combine harvest	Machine	1	527.68	527.68
Transport	Metric ton	6	89.30	535.80
Miscellaneous				1014.77
Technical Assistance	Fee	1	146.13	146.13
Insurance	Fee	1	316.61	316.61
Interest	Rate	1	552.04	552.04
SUBTOTAL				**9944.92**
Rent plot	Machine	1	1623.63	1623.63
Total Production Costs				11568.56
Cost of water and fixed costs				(3350.78)
Total Variable costs				8217.78

Crop budget for cotton, from 2008-2009, and updated to April 2011 MXN (INCP 2011).

	Units				Cost per ha
	Times	Quantity	Unit	Cost	
Prepare soil					2491.42
Plow	1	1	ha	622.85	622.85
Disk	2	1	ha	332.19	664.38
Leveling	2	1	ha	332.19	664.38
Rows	1	1	ha	332.19	332.19
Make borders	1	1	ha	207.62	207.62
Planting					793.93
Planting permit	1	1	ha	24.91	24.91
Seed	1	15	kg	31.89	478.35
Planting	1	1	ha	290.67	290.67
Fertilization					5356.55
Urea (46-00)	2	125	kg	11.03	2757.17
Ammonium Phosphate (11-52-00)	1	100	kg	14.12	1411.80
Ammonia (NH3) y Custom Application	1	120	kg	7.47	896.91
Land Application	2	1	ha	145.33	290.67
Irrigation					1631.88
Water	6	25	lts	6.23	934.28
Irrigation	6	1	ha	66.44	398.63
Cleaning canals	2	1	Day	83.05	166.09
Irrigation and conservation permit	1	1	ha	132.88	132.88
Pest and Weed Control					2387.53
Azodrin	1	1.5	lts	140.35	210.52
Tamaron	1	1.5	lts	156.96	235.44
Karate	1	0.6	lts	412.75	247.65
Gusathion	1	3.5	lts	117.93	412.75
Aerial application	2	1	ha	207.62	415.24
Trifluoralina	1	1.8	ha	90.52	162.94
Land application	1	1	ha	207.62	207.62
Defoliant (DEF)	1	1.5	ha	163.60	245.40
Defoliant	1	0.25	ha	999.89	249.97
Harvest					3612.56
Custom picking	1	1	ha	2740.56	2740.56
Transport	1	1	ha	581.33	581.33
Shredding stock	1	1	ha	290.67	290.67
Miscellaneous					1636.03
Technical assistance	1	1	ha	232.53	232.53
Insurance	1	1	ha	581.33	581.33
Interest	1	1	ha	822.17	822.17
Total Production Costs					17909.90
Subtracting cost of water and fixed costs					(2570.31)
Total Variable Costs					15339.59

Appendix E. Risk Considerations for Crop Portfolios: Definitions and Calculations

Definitions

Table 1E: Terminology and Definitions

Terminology	Definition
Risk neutral	Individuals are classified as risk neutral if they make decisions based upon the highest expected return, regardless of probabilities with varying levels of gain or loss.
Risk averse	Individuals are classified as risk averse if they are willing to accept a lower return if it is associated with lower risk.
Expected value	The expected value is similar to a weighted average where the weights are the respective probabilities, and is calculated as the sum of each variable multiplied by the probability of that variable occurring.
Expected return	The expected return is calculated as the sum of each possible net return (where the net return equals revenues minus costs) multiplied by the probability of that net return occurring.
Variability	The variability is the full range of movement of the variables over time.
Variance	Variance is the square of the deviations around the mean and can be described as the extent of positive and negative deviation from the mean.
Standard Deviation	Standard deviation (SD) is the extent of deviation around the mean of a variable. The SD is the square root of the variance.
Covariance	The covariance can be thought of as the way two variables, x and y, move together in the same or opposite direction with respect to their deviation from mean values. (Variance is a special case of covariance, where the two variables are the same).
Correlation	The correlation is bounded by -1 and 1, and describes the direction of movement that two variables have in relation to the other. A correlation of 1 means that two variables move in exactly the same

	direction; a correlation of zero implies that the two variables are unrelated; and a correlation of -1 means that as one variable increases the other decreases, or vice versa.
Coefficient of variation	The coefficient of variation (CV) is the standard deviation divided by the expected value and is a measurement of dispersion (Jung, Shambora and Choi 2010).

Definitions provided in this table are adapted from Boehlje and Eidman (1984).

Steps for Calculating the Coefficient of Variation and Crop Correlations

The following exercises will offer detailed instructions for calculating the coefficient of variation for alfalfa from Yuma County data from Table 10. Then, the steps will be shown for calculating the crop correlation between alfalfa and cotton. Although specific numbers are inserted in the instructions, the steps are easily generalized to be applicable to any crop or region. Refer to Table 1E for definitions of terms used related to risk management.

The standard deviation is needed to calculate the coefficient of variation. Standard deviation can be written in the following format:

$$s = \sqrt{\frac{\sum (x-\mu)^2}{n-1}}$$, where:

s=Standard deviation

Σ=Sum of

x=Gross revenue per acre (USD)

μ=Mean gross revenue for the time period

n=Number of years

Table 2E. Calculating Coefficient of Variation for Alfalfa

A	B	C	D	E
Calculating the Standard Deviation and Coefficient of variation of Alfalfa				
Year	Gross Revenue/Acre (USD)	Mean Gross Revenues for 2000-2008	Column B- Column C	Column E squared
2000	814.98	1098.65	-283.67	80468.67
2001	816.75	1098.65	-281.9	79467.61
2002	862	1098.65	-236.65	56003.22
2003	866.36	1098.65	-232.29	53958.64
2004	995	1098.65	-103.65	10743.32
2005	1129.64	1098.65	30.99	960.3801
2006	1160.96	1098.65	62.31	3882.536
2007	1419.4	1098.65	320.75	102880.6
2008	1822.8	1098.65	724.15	524393.2
			Divide 912758.2 by n-1	912758.2
			Take square root of 114094.8	114094.8
			Standard Deviation for Crop Gross Revenues, Alfalfa:	**337.78**
			Standard deviation divided by mean	0.307449
			Coefficient of Variation:	31%

Table 2E was inserted from an excel document and shows all of the steps required for calculating the coefficient of variation, as elaborated in the following steps.

1) Column B, Gross Revenue/Acre (USD), shows the gross revenues for each year from 2000 until 2008 for alfalfa from Yuma County, Arizona.
2) Column C, Mean Gross Revenues for 2000-2008, is column B summed and divided by nine, since there are nine years in the sample (Shown as μ in the standard deviation equation).
3) Column D = Column B – Column C. (Shown as $(x-\mu)$ in the standard deviation equation).
4) Column E = (Column D)^2. (Shown as $(x-\mu)^2$ in the standard deviation equation).
5) As shown in the table, the values of column E for years 2000-2008 are summed to get a value of 912758.2. (Shown as $\Sigma(x-\mu)^2$ in the standard deviation equation).
6) Divide 912758.2 by 8 to get 114094.8. (Shown as $(\Sigma(x-\mu)^2)/(n-1)$ in the standard deviation equation).
7) Take the square root of 114094.8 to get 337.78. That value is the standard deviation for alfalfa from Table 11.
8) Divide 337.78 by 1098.65 (the mean) to get 0.307449. Multiply by 100 to convert that number to a percent. The coefficient of variation is 31%, also listed in Table 11. The CV's in this

guidebook range from 12% to 46%, with a higher CV indicating greater risk. A CV of 31% for alfalfa could be considered moderately risky. The CV provides more useful information when compared to CV's for other crops or other farm income sources.

Next, we will show the calculations for the crop correlation. To calculate the crop correlation, we need the following information to calculate covariance:

$$\text{cov}(x,y) = \frac{\sum (x-m_x)(y-m_y)}{n-1}$$, where

Cov(x,y)= covariance, in the context of this guidebook, of any two crops

Σ=Sum of

x=Gross revenue per acre (USD) for the first crop

m_x=Mean gross revenue for the time period for the first crop

y=Gross revenue per acre (USD) for the second crop

m_y=Mean gross revenue for the time period for the second crop

n=Number of years

$$corr(x,y) = \frac{\text{cov}(x,y)}{s_x s_y}$$, where

Corr(x,y)= Crop correlation between two crops x and y

S_x=Standard deviation of crop x

S_y=Standard deviation of crop y

Table 3E. Correlation of Alfalfa and Cotton

A	B	C	D	E	F	G	H
Calculating the Covariation and Correlation of Alfalfa and Cotton							
Year	Gross Revenue/Acre (USD) - Alfalfa	Mean Gross Revenue Alfalfa	Column B - Column C	Gross Revenue/Acre (USD) Cotton	Mean Gross Revenue Cotton	Column E - Column F	Column D * Column G
2000	814.98	1098.65	-283.67	610.81	791.88	-181.07	51364.44
2001	816.75	1098.65	-281.9	654.12	791.88	-137.76	38834.86
2002	862	1098.65	-236.65	847.29	791.88	55.41	-13112.51
2003	866.36	1098.65	-232.29	887.8	791.88	95.92	-22281.00
2004	995	1098.65	-103.65	829.81	791.88	37.93	-3931.33
2005	1129.64	1098.65	30.99	805.62	791.88	13.74	425.77
2006	1160.96	1098.65	62.31	813.71	791.88	21.83	1360.16
2007	1419.4	1098.65	320.75	868.37	791.88	76.49	24533.81
2008	1822.8	1098.65	724.15	809.4	791.88	17.52	12686.30
Sum Column H for years 2000-8; then divide 89880.50 by n-1							89880.50
Divide 11235.06 by the product of the standard deviation of alfalfa and cotton							11235.06
Crop Correlation for Alfalfa and Cotton:							**0.35**

Table 3E was inserted from an excel document and shows all of the steps required for calculating the crop correlation for alfalfa and wheat, as elaborated in the following steps.

1) Columns A-D in Table 3E are the same as columns A-D in Table 2E. Then, the following three columns, E, F and G, have the equivalent data which will be needed to compute the covariance. Begin by following steps 1-3 from the previous instructions, this time for cotton.
2) In Column H, multiply Column D by Column G. In other words, multiply *(x-m_x)* for alfalfa for the year 2000 (-283.67) by *(y-m_y)* for cotton for the year 2000 (-181.07). Then, proceed to multiply the respective values for 2001 and continue until 2008.
3) Sum the values in Column H for the years from 2000-8 to get 89880.50. (Shown in the covariance equation as $\Sigma(x-m_x)(y-m_y)$).
4) To complete the calculation for covariance of alfalfa and cotton, divide the answer from number 3 by n-1, or by 8, to get a value of 11235.06.
5) The correlation is simply the covariance divided by the product of the standard deviations.
    a. Locate the value for the standard deviation for alfalfa from Table 2E, which equals 337.78.

b. Use the value for the standard deviation for cotton from Table 11 from the Risk Considerations for Crop Portfolios section of this guidebook. That value is 95.06.

c. $S_x * S_y$ = 337.78 * 95.06 = 32109.37.

d. Covariance divided by ($S_x * S_y$) = 11235.06/32109.37 = 0.35. Considering that a correlation of 1 is a perfect correlation, and a correlation of 0 means that there is no relationship between the two variables, then a correlation of 0.35 indicates a weak positive relationship between alfalfa and cotton revenues.

Appendix F. Consumptive Use Overview and Analysis

Correctly identifying the units of consumptive use that are associated with each acre of irrigated cropland proposed for temporary fallowing can be challenging. Given limitations to data collection, lack of updated field data, and limited budgets to improve consumptive use data, high levels of accuracy in calculating historic consumptive use for purposes of forbearance negotiations may not be possible. Inaccuracies do carry consequences. If crop consumptive use is overestimated and that overestimate is used to calculate transferrable quantity, then there is the risk of allowing a transfer of water to other users that exceeds what was historically being consumptively used. This would lead to additional depletions and possible injury to downstream water users and to ecosystems. In many western U.S. states, state water regulations specify procedures for quantifying consumptive uses for the purpose of water transfers, with a particular emphasis on preventing injury to downstream water right holders.

Investing effort into obtaining accurate, up-to-date, and location-specific crop consumptive use figures will improve overall accuracy of forbearance contracts. In this section of the guidebook, the equation for calculating crop evapotranspiration is shown, in addition to a bulleted list of general factors leading to variation in crop consumptive use.

- <u>Crop consumptive use calculation</u>:

Agricultural consumptive use in the Lower Colorado River Accounting System (LCRAS) includes total crop consumptive use plus canal evaporation. Crop consumptive use, on the other hand, typically refers only the volume of water that the crop consumes during the production cycle, either through incorporation into plant biomass or through evapotranspiration, and which is not directly returned to the local hydrologic system as either seepage into groundwater aquifers or as surface water runoff.

Crop consumptive use, also referred to as crop evapotranspiration (ET), is measured by the following equation, where cotton is used as an example (LCRAS 2009, 14):

ET cotton = n[(ET_0 * Kcotton) – Effective PPT] * AC_cotton/12

Where:
ET cotton = Annual ET by cotton for the field in question (acre-feet)

n	=	Summation for n time (monthly)
ET_0	=	Daily reference ET (inches)
Kcotton value)	=	Daily ET coefficient specific to cotton (dimensionless) (Each crop has a K
AC_cotton	=	Acreage of cotton for the total number of parcels in question (acres)
Effective PPT	=	Effective precipitation

Some soil scientists consider the crop ET equation analogous to a supply and demand equation. [11]The ET_0 represents the climatic conditions from weather station data, and the ET_0 can be considered the demand – the hotter or cooler, more humid or dryer the climate is, the more or less the atmospheric demand increases for water. The K represents the supply – the natural rate of evapotranspiration of each crop relative to another crop. Therefore, the equation involves multiplying the ET_0 by the crop coefficient K, showing the interaction between weather and crop type.

Then, the precipitation is subtracted. Next, because evapotranspiration rates change significantly as a plant develops, a new crop ET is calculated on a daily basis, and all daily values are summed to get an annual value. Finally, the value is divided by 12 inches per feet to get a value in acre-feet (precipitation and daily ET values are in inches).

- Crop consumptive use is sensitive to spatial and temporal variation:

Crop consumptive use is strongly impacted by weather and therefore will vary from region to region and year to year. Solar radiation is considered the primary influence on consumptive use, followed by wind. Because climatic conditions change from year to year, crop consumptive use will change from each year. Refer to Table 1F for an example of how crop ET has varied annually for alfalfa, cotton, lettuce and wheat in Yuma County, Arizona. Note that the eight-year average was used in the NRTW calculations for Yuma County to provide a consistent value over the two time-periods shown in tables 2, 3, 4, and 5.

LCRAS uses weather station data for calculating crop consumptive use, meaning that the regional data can be only as accurate as the nearest weather station, yet microclimates within a region can

[11] Dr. Paul Brown (Extension Specialist and Research Scientist Biometeorology, Department of Soil, Water and Environmental Science, University of Arizona), interviewed by Elizabeth Schuster, February 2, 2011 and June 6, 2011.

also affect crop ET. Soil scientists are unclear on the extent to which microclimates effect crop ET, and more research is required in this area to improve crop consumptive use estimations.

Table 1F. Crops' ET in AF per year, Yuma County, Arizona (LCRAS 2002-2008)

	2002	2003	2004	2005	2006	2007	2008	**Average**	SD
Alfalfa	5.63	5.43	5.28	5.16	5.73	5.84	5.40	**5.50**	0.25
Cotton	3.47	3.42	3.41	3.39	3.62	3.60	3.41	**3.47**	0.10
Lettuce	1.38	1.28	1.12	1.18	1.42	1.41	1.21	**1.29**	0.12
Wheat	2.07	1.83	1.86	1.67	1.92	2.04	1.92	**1.90**	0.14

- <u>Harvest date and consumptive use</u>:

Farmers in a given region tend to harvest crops over a broad window of time. For instance, in Yuma County, farmers may harvest cotton from August 10 until Thanksgiving, or even later. The difference in harvest date can have a direct impact on crop consumptive use.

> ***Example***. For cotton in Yuma County in 2008 (see Table 1F), 3.41 AF is the consumptive use and was calculated assuming an October harvest. However, September and October ET is 0.58 and 0.157 (LCRAS 2008), respectively, so an August harvest would result in a crop consumptive use value of about 2.67, which is 28% lower.

Errors as large as 28%, aggregated over hundreds of acres, could lead to an inaccurate estimation of crop consumptive use of water when negotiating a temporary transfer of irrigation water to a different use. Consequently, local harvest dates are another factor to be considered in designing and implementing irrigation forbearance programs.

Appendix G. Acronyms and Bilingual Glossary

Acronyms

English	Spanish
Acre-feet: AF	Acre-pie: AP
Autonomous University of Baja California: UABC	Universidad Autónoma de Baja California: UABC
Bushel: BU	Bushel: BU
Coefficient of Variation: CV	Coeficiente de variación: CV
Consumer Price Index: CPI (for the US)	Índice de Precios al Consumidor: CPI
Economic Research Service: ERS	Oficina de Investigaciones Económicas: ERS
Farm Service Agency: FSA	La Agencia de Servicios Agrícolas: FSA
Hundred weight: CWT	Cien libras: CWT
International Maize and Wheat Improvement Center: CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo: CIMMYT
Loan Deficiency Payment: LDP	Los préstamos de pago compensatorios: PPC
Lower Colorado River Accounting System: LCRAS	Sistema de Contabilidad del Bajo Rio Colorado: LCRAS
Mexican pesos: MXN	Pesos mexicanos: MXN
National Agricultural Statistics Service: NASS	Servicio Nacional de Estadísticas Agrícolas: NASS
National Index for Consumer Prices: INPC (for Mexico)	Índice nacional de precios al consumidor: INPC
National Oceanic and Atmospheric Administration's: NOAA	La Administración Nacional Oceánica y Atmosférica: NOAA
Natural Resources Conservation Service: NRCS	Agencia de Conservación de Recursos Naturales: NRCS
Net Return to Water: NRTW	Ganancia Neta del Agua: GNDA
Office of Information for Sustainable Rural Development: OEIDRUS	Oficina Estatal de Información para el Desarrollo Rural Sustentable: OEIDRUS
Producer Prices Paid Index: PPPI	Indice de precios pagado al productor:
Secretary of Agriculture, Livestock, Rural Development, Fisheries, and Food: SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca, y Alimentación: SAGARPA
Sector Applications Research Program: SARP	Sector de Aplicaciones del Programa de Investigación: SARP
Standard deviation: SD	Desviación Estándar: DE
U.S. Dollars: USD	Dolares estadounidenses: USD
United States Department of Agriculture: USDA	Departamento de Agricultura de los Estados Unidos: USDA

Glossary

English	Spanish
Agricultural extension agent	Extensionista agropecuaria
Allocation	Asignación
Climate Change	Cambio climático
Coefficient of variation	Coeficiente de variación
Consumptive use	Uso consuntivo
Cooperative Extension	Extensión Agropecuaria
Correlation	Correlación
Covariance	Covarianza
Crop Budget	Presupuesto de cultivo
Crop Portfolio	Portafolio de cultivos
Crop revenue	Ingresos de Cultivos
Demand	La demanda
Durum wheat	Trigo cristalino
Evaporation	Evaporación
Evapotranspiration	Evapotranspiración
Expected return	Ganancia esperada
Expected value	Valor esperado
Expenses	Gastos
Fallowing	En barbecho
Farm/crop budget	Presupuesto de cultivos
Federal farm support payments	Pagos federales de apoyo a la agricultura
Fixed Costs	Costos fijos
Forbearance programs	Programas de pago por abstención de riego
Gross returns	Ganancia total
Gross revenues	Venta total
Habitat flows	Flujos de habitat
Heterogeneity	Heterogeneidad
Irrigated agriculture	Agricultura de regadio
Irrigation district	Distrito de riego
Jurisdiction	Jurisdicción
Legal entitlements	Derechos legales
Loan deficiency payment	Prestamos de pagos compensatorios
Market price comparison method	El método de comparación de precios de mercado
Net growth	Crecimiento neto
Net Income	Ingresos netos
Net Returns	Ganancia neta

Net Returns to Management and Risk	Ganancia neta a la gestión y al riesgo
Net Returns to Water	Ganancia neta del agua
Net Returns to Water per acre-foot of water consumed	Ganancia neta del agua por acre-pie de agua consumida
Net revenues	Venta neta
“No harm” principle	Principio de “no dañar”
Permanent water transfer	Intercambios de agua permanentes
Prior appropriation	La doctrina de apropiación previa
Risk averse	Aversión al riesgo
Risk neutral	Neutral al riesgo
Risk Preferences	Preferencias de riesgo
River basin	Cuenca fluvial
Seepage	Filtración
Stakeholders	Otras partes interesadas
Standard deviation	Desviación estándar
Temporary water transfer	Intercambios de agua temporales
Time period	Periodo de tiempo
Total revenue	Ingreso total
Transpiration	Transpiración
Upland cotton	Algodón Americano (sometimes referred to as “algodón Americano *upland”* and in other regions simply as “algodón” *)*
Variability	Variabilidad
Variable Costs	Costos variables
Variance	Varianza
Water acquisition programs	Programas de adquisición de agua
Water consumption	Consumo de agua
Water market transaction	Transacciones del mercado de agua
Water rights	Derechos de agua
Water supply reliability	Fiabilidad del Suministro de agua
Water transfer	Intercambios de aguas
Water Users	Los usuarios del agua
Water-crop production function	Función de producción del cultivo de agua bajo diferentes láminas de riego

Appendix H. Conversion Tables for Unit of Measurement

Conversion Table to Metric Units

1 Bushel of wheat	60 pounds	27.22	kilograms
1 Bushel of alfalfa	60 pounds	27.22	kilograms
1 Bushel of corn (grain)	56 pounds	25.4	kilograms
Cwt	100 pounds	45.36	kilograms
1 ton (also called short ton)	2,000 pounds	907.18	kilograms
2,204.62 pounds	1,000 kilograms	1	metric ton
1 acre	0.4046 hectares		
1 acre-foot	304.8 millimeters	1,233	m^3 per acre

Note: In the data shown for Yuma County, cotton is in the processed form, classified into seeds and lint, whereas Mexican cotton is listed as "*algodón hueso*," meaning it is unprocessed. Therefore, we cannot make a direct unit to unit conversion.

Monetary conversions

Currency Conversion		
April 2011	1 USD	11.7 MXN

Inflation adjustments for the United States

Because the prices had been converted to January 2010 prices using the CPI Inflation Calculator, for the final version of the guidebook, all Yuma and Colorado prices and costs were further adjusted to April 2011 prices. The April 2011 CPI value was divided by the January 2010 CPI value to get a ratio of 1.04. Then, all prices and costs were divided by 1.04.

CPI adjustment	
January 2010	216.687
April 2011	224.906
	1.03793

Inflation adjustments for Mexico

The crop budgets for wheat began in December 2007. Therefore, the value from the INPC for agricultural prices for April 2011 was divided by the value from the INPC for December 2007, resulting in a value of 1.23. Then, all prices and costs from the Mexicali Durum wheat crop budgets were divided by 1.23 to adjust for inflation.

INPC adjustment	
December 2007	81.1633
April 2011	99.9773
	1.2318

The crop budgets for cotton began in April 2008. Therefore, the value from the INPC for agricultural prices for April 2011 was divided by the value from the INPC for April 2008, resulting in a value of 1.20. Then, all prices and costs from the Mexicali cotton crop budgets were divided by 1.20 to adjust for inflation.

INPC adjustment	
April 2008	83.0285
April 2011	99.9773
	1.204133